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A Treatise on

BOILERS, STEAM ENGINES, THE LOCOMOTIVE, ELECTRICITY, MACHINE SHOP PRACTICE, AIR BRAKE PRACTICE, ENGINEER'S CATECHISM, GAS, OIL, TRACTION AND AUTOMOBILE MOTORS, REFRIGERATION, ETC. ETC.

By

CALVIN F. SWINGLE, M. E.
EDITOR-IN-CHIEF

And a Corps of
ENGINEERS AND MECHANICAL AND ELECTRICAL EXPERTS

SEVEN VOLUMES
Containing Thirty-five Hundred Pages and Fifteen Hundred Illustrations

INTERNATIONAL SCHOOL OF ENGINEERING
350 WABASH AVE., CHICAGO

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Introduction

THIS Encyclopedia has been compiled from the latest and most practical papers of the International School of Engineering, by Calvin F. Swingle and other authors. It is intended to furnish practical instruction in the subjects, covered in each volume, for those who are not in a position to take up a correspondence course or attend a School of Engineering. Each volume is complete in itself, and will be found to be of great practical value to the mechanic or student who desires to obtain the latest and best information on the subjects contained therein. Numerous practical examples are given in each volume, which help to bring out the fundamental principles involved and also fix the essential points in the reader's mind.

Experience in the workshop, laboratory and classroom of years duration have been necessary in the preparation of the different sections of this work, and the subjects contained in each, have been tested by actual use as to their practical value to the person who desires to be up in the latest and best shop or engine-room practice. This Encyclopedia has been compiled with the idea of making it of value to those who are not in a position to benefit themselves by a technical school course.

Electricity for Engineers

CHAPTER I

The Electric Current—The Ampere—The Volt—The Ohm—The Watt—Divided Circuits.

The Electric Current. All electrical phenomena with which we have to deal are produced through the medium of the electric current. This current flows only in a conductor of electricity. Among the most noteworthy of the conductors are the various metals; the most useful, and in fact the only one in general use for light and power purposes, being copper.

Every conductor offers some resistance to the flow of current, just as every pipe offers resistance to the flow of steam or water. Just how this resistance varies we shall see later on. In order to familiarize ourselves with the most important electrical phenomena let us consider Fig. 1. The current is assumed to leave the battery at the +, or positive, pole and flow along the wires, etc., to the negative, or – pole, and as it passes through the coils of wire wound about the iron bar it produces magnetism in the bar. If the bar is of soft iron the magnetism lasts only while the current is flowing, but a bar of hardened steel will permanently retain its magnetism. The current will also heat the incandescent lamp until it emits light, and the fine wire, *R*, to the melting point, if desired. In passing through the water in the jar, it will decompose it, forming oxygen and hydrogen gas. If, instead of water, the jar is filled with a proper solution, one of the copper plates in the solution will be gradually eaten away and the other added to. If we now disconnect our wires from the battery and connect 1 at 2, and 2 at 1, the chemical action in the jar will be reversed, the lamp and fine wire, *R*, will heat as before, no difference being noticeable. The iron bar will also be a magnet as before, but the end that before attracted the north seeking end of a compass needle will now repel it and attract the south seeking end of the same needle. The wire which connects the various devices, and the devices themselves, constitutes an electric circuit, and the current is said to flow in such a circuit along the wire, just as water flows in a pipe. The solid lines form what is known as a series circuit, while the dotted lines form a multiple circuit. In the latter case, each piece of apparatus receives current independent of the others. In the series circuit the same current passes through all. If the small wire *a* is connected to *b*, no current will flow through R; it

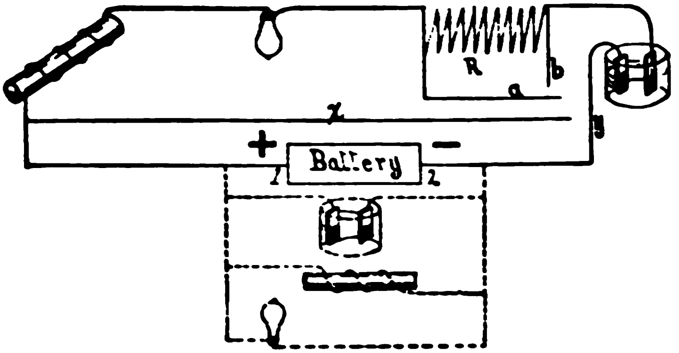


FIGURE 1.

will all flow through *a* and *b*. If the wire X be connected to Y, all current will flow through it and none through any other part of the circuit. The current obeys the same law as does water; it takes the path which offers the least resistance to its flow.

Such substances as effectually prevent current from flowing through them are known as insulators. Some of them are

Dry Air,
Glass,
Silk,
Asbestos,
Porcelain,
Cotton,
Rubber,
Mica,
Shellac,
Oil,
Paraffine,
Wool,
Paper,
Gutta Percha,

and because the following substances have a low resistance they are known as conductors of electricity. Their relative conductivity is in the following order, silver being the best:

Silver,
Copper,
Gold,
Platinum
Iron,
Tin,
Lead, etc.

The Ampere. The ampere is the unit of volume or rate of flow, and in speaking of a flow of so many amperes, we mean substantially the same thing, electrically speaking, as though we referred to so many gallons of water, mechanically speaking. The number of amperes flowing over a wire deliver power, much or little, proportional to the electromotive force or pressure under which they flow; just as the number of gallons of water flowing through a pipe toward a water wheel deliver a large or small quantity of power to the wheel, proportional to the pressure under which the water flows. If 100 amperes were flowing at a pressure of 10 volts they would produce the same power as though there were 10 amperes flowing at 100 volts, exactly as 100 gals. of water flowing at a pressure of 10 lbs. to the square inch would produce the same power as 10 gals. flowing at a pressure of 100 lbs. to the square inch. In both cases, however, for convenience, we have not considered the size of either wire or pipe, but with the wire, as with the pipe, as we increase the diameter we decrease the friction or resistance. In speaking of the gallon we, of course, have something material on which we can base the unit gallon. We may take a vessel 1 ft. wide, 1 ft. long and 1 ft. high, and this vessel will hold 1 cu. ft. of water. This cubic foot would contain 7½ gals.; but in the case of the ampere we must adopt another method. We shall take an earthenware tank in which is contained a solution of copper sulphate and add one-tenth of one per cent. sulphuric acid. We shall next take two copper plates and hang them into this solution, keeping them spaced one inch apart, vertically. Having washed these plates in clear water, rounded off the corners and dried them thoroughly, we must next weigh them very carefully before submerging them in the liquid. We may now connect both plates to a source from which we can obtain a current of electricity and allow the current to flow from one plate to another, through the liquid, for a period of time which we must measure by a watch or clock. After current has flowed for several hours we will remove the plates, wash them in clean water, and then dip in a bath of water containing a very small amount of sulphuric acid to prevent oxidization, dry them and carefully weigh them again. It will be found that the negative plate has increased in weight by what is called electrolytic action. Now weigh the negative plate and ascertain the exact number of grammes of copper deposited on its surface, or, in other words, find how many grammes heavier the plate is now than it was before it went into the bath. With these data in our possession we will multiply the time in seconds that current was passing through the plates by .000329 and divide the number of grammes deposited on the plate by the result. The quotient will be the number of amperes that passed from plate to plate. This I give simply to show you the manner in which the ampere can be ascertained. It is that current which will deposit .000329 gramme per second on one of the plates of a voltameter, as above described. It is also the current produced by one volt acting through a resistance of one ohm.

In other words, the ampere is that current which would be forced over a wire having a resistance of one ohm by a pressure of one volt.

The ampere-hour is the unit of electrical quantity in general use. It is the quantity of electricity conveyed by one ampere flowing for one hour, or one-half ampere flowing for two hours; or again, one-fourth ampere flowing for four hours. In each case the sum total would be one ampere-hour. It must, however, be noted that an ampere-hour with the pressure at 110 volts would deliver just one-half as much power as an ampere-hour at 220 volts.

An ordinary 16 candle-power 110 volt incandescent lamp requires a current of about one-half an ampere,

[illegible]

[illegible] part of an [illegible]

The Ampere. [illegible] quantity. [illegible] ampere [illegible]

The Volt. [illegible] potential, we [illegible] when [illegible] a steam gauge [illegible] a positive and a negative [illegible] a certain [illegible] artificial pressure [illegible] pressure. The difference [illegible] pressure between two wires we [illegible] difference of potential between [illegible] and the atmosphere [illegible]. The steam gauge [illegible] operates it, and hence the pressure [illegible] of the pipe does not flow [illegible] other words, the resistance offered [illegible] pressure prevents the water from escaping into the atmosphere. In the case of the volt-meter the resistance of the wires used in its construction prevents any great quantity of electricity from flowing out of the positive wire and into the negative through the volt-meter coil. If the gauge were accidentally broken off the pipe, the resistance to the pressure on the inside of the pipe would be greatly lowered and allow the water to flow into the atmosphere. If a piece of ordinary wire were connected to the positive and negative wires, where we have just connected our volt-meter, it would form a path of such low resistance and allow all the current to flow through it, so there would be no pressure indicated in the volt-meter. This would be called a "short circuit." With a volt-meter there is always a small amount of current flowing from a positive to a negative wire through the coil in the meter. This current is neccesary to produce the reading on the meter, but we need not consider this current at present, the quantity being very small.

One volt (unit of pressure) will force one ampere (unit of current) over one ohm (unit of resistance).

Potential is a term quite frequently used to express the same idea as voltage or electromotive force, but its meaning is somewhat different. Suppose that a steam engine is working with 100 lbs. of pressure at the throttle valve, and exhausting into a heating system or system of piping that offers a back pressure of 5 lbs. to the square inch; in other words, the resistance to the flow of steam out of the exhaust pipes of this engine is such that the remaining pressure, when the engine has exhausted, is 5 lbs. Now it will readily be seen that the total pressure utilized to do the work would be 100 lbs. less 5 lbs., or 95 lbs., and therefore the potential would be 95 lbs. Now, if we are using electricity at 100 volts pressure, and lose 5 volts in overcoming resistance, we have a potential of 95 volts left. Whenever work is done by a steam engine a certain amount of pressure is lost by condensation, doing work and by overcoming friction. This loss may be considered the same as a loss of potential, for in the use of electricity any loss in pressure of volts that may occur from doing work or overcoming resistance is called a loss of potential.

In open arc lamps the loss of potential across the terminals or binding posts is about 50 volts; that is, 50 volts have been absorbed or used in producing light. You can now readily understand that electromotive force means force, pressure, energy, and that by potential we mean the capacity to do work or the effective pressure to do work. While we are speaking of electromotive force we may consider some of the advantages of high and low electromotive forces. High electromotive force, like steam at high pressure, is far more economical in transmission or utilization because the quantity may be that much smaller.

When transmitted to great distances, high electromotive forces, like high water or steam pressures, are far more desirable on account of the reduction in friction losses; but this is partially offset by the necessity of using, in water transmission, a much stronger pipe for the high pressure than would be necessary for the low pressure, and in the transmission of current at a high electromotive force or pressure it becomes necessary to use wires with far better insulating material than would be required for the transmission of electricity at low pressure. Increasing the pressure or electromotive force always means more danger, even if you know the pipes are extra strong or the insulation of the wire is of unusually high resistance; for if anything should happen the consequences would be far more serious with high than with low pressures. But notwithstanding all this, engineers are continually increasing the pressures of electrical machinery.

Static electricity is a term applied to electricity produced by friction, and a static discharge of electricity usually consists of an infinitely small quantity but a very high electromotive force or pressure. Discharges of lightning are extremely high in voltage, but the quantity of current that flows is very small.

The Ohm. The ohm is the unit of resistance. Resistance, electrically speaking, is much the same thing as friction in mechanics. If a wire or pipe of a certain length is delivering 10 gals. or 10 amperes at a pressure of 100 lbs. or 100 volts, and we propose to double the flow without increasing the pressure, it will be necessary for us to increase the diameter of the pipe and wire in order to lower the resistance of the wire and the friction of the pipe to one-half of what it was before. If we desire the best results from the pipe, we lower its friction by reaming out all burrs and avoiding all unnecessary bends and turns; likewise if we desire the best results from the wire we will have the copper of which it is constructed as nearly pure as possible, and we will install the wire where its temperature will not be unnecessarily high, avoiding boiler rooms and other hot places. Resistance of the wire increases slightly with an increase in temperature.

For every additional degree centigrade the resistance of copper wire increases about 0.4 per cent., or for every additional degree Fahrenheit about 0.222 per cent. Thus a piece of copper wire having a resistance of 10 ohms at 32° F. would have a resistance of 11.10 ohms at 82° F. An annealed wire is also of lower resistance than a hard drawn wire of the same size. A good idea of the value of an ohm may be had from the following table, which gives the length of different wires required to make one ohm resistance.

FEET PER OHM OF WIRE (B. & S.).

94	feet of No.	20	605	feet of No.	12
150	"	18	961	"	10
239	"	16	1529	"	8
380	"	14	2432	"	6

3867 feet of No. 4

We have not as yet established a unit of mechanical friction, therefore when we speak of mechanical friction we refer to it as requiring a certain quantity of power to overcome it. When, however, resistance to the flow of electricity is spoken of it is referred to as so many ohms. It can be measured in several ways, the most reliable and convenient being by an instrument called the Wheatstone Bridge. It can also be calculated if the length and diameter of the wire or conductor is known, as will be shown later on.

The basis of all electrical calculation is Ohm's law. This law reads:

"The strength of a continuous current in a circuit is directly proportional to the electromotive force acting on that circuit, and inversely proportional to the resistance of the circuit." In other words, the current is equal to the volts divided by the ohms. Expressed in symbols, $C = E/R$; C being current, E voltage, and R resistance. If an incandescent lamp having a resistance of 200 ohms be placed in a socket where the pressure is 115 volts, the resulting current through such a lamp would be 115 divided by 200, or .575 of an ampere.

From the formula $C = E/R$, two others are deduced. The volts divided by the amperes equal the ohms, $E/C = R$.

The amperes multiplied by the ohms equal the volts, $C \times R = E$.

The Watt. The watt is the unit of power. It is an ampere multiplied by a volt; just as the unit of mechanical power, called the foot pound, is the result of the pound multiplied by the space in feet through which it moves. If a current of say 100 amperes, flcws over a wire at a pressure of 10 volts, the power delivered will equal

100 amperes × 10 volts = 1,000 watts. If a current of 10 amperes flows over a wire at a pressure of 100 volts, the power would be exactly the same, 10 amperes × 100 volts, or 1,000 watts. But, of course, in the first case it would require a wire ten times as large to deliver the 1,000 watts as would be necessary in the latter case. If a weight of 10 pounds were being elevated through space at the rate of 100 ft. per minute the power equivalent would be 10 lbs. × 100 ft., or 1,000 ft. lbs. If an arc lamp consumes 10 amperes at a pressure of 70 volts, its power consumption is 10 × 70, or 700 watts. One watt is the power developed when 44.25 ft. lbs. of work are done per minute. Seven hundred forty-six watts equal one horse power. The watt-hour is the unit of electric work, and is a term employed to indicate the expenditure of one watt for one hour. The kilo watt-hour is the term employed to indicate the expenditure of an electric power of 1,000 watts for one hour.

The work done per second when a power of one watt is being developed is called the joule, and a joule is equal to .7375 ft. lbs.

Electromotive force times current equals watts. The square of the current multiplied by the resistance equals watts; and the voltage multiplied by itself and divided by the resistance equals watts. Expressed in symbols, these explanations would look like this:

$$W = E \times C. \qquad W = C^2 \times R. \qquad W = E^2 \div R.$$

First. If we have an electromotive force or voltage of 10 volts and a current of 20 amperes, we have 10 × 20 = 200 watts.

Second. If we have a current of 10 amperes and a resistance of 30 ohms, we would have 10 × 10 × 30 = 3,000 watts.

Third. If we have an electromotive force or voltage of 10 volts and a resistance of 20 ohms, we would have 10 × 10, or 100 ÷ 20, or 5 watts.

In the above formulas E stands for voltage, C for current, R for resistance and W for watts.

Divided Circuits. Currents of electricity, although they have no such material existence as water or steam, still obey the same general law; that is, they flow and act along the lines of least resistance. If a pipe extending to the top of a ten story building had a very large opening at the first floor, it would be impossible to force water to the top floor. All the water would run out at the first floor. If the opening at the first floor were small only a part of the water would escape through it, some would reach the top of the building. The flow of water in each case is inversely proportional to the resistance offered to it by the diferent openings.

The same thing is true of currents of electricity. Where several paths are open to a current of electricity the flow through them will be in proportion to their conductivities, which is the inverse ratio of their resistances. As an illustration, the current flow through all of the lamps, Fig. 2, is the same, because each lamp offers the same resistance. But if we arrange a number of lamps as in Fig. 3, the lamps in series will offer twice as much resistance as the single

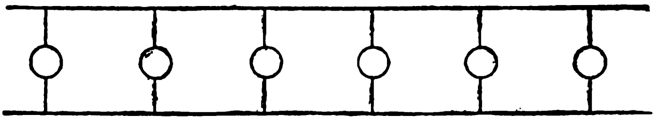


FIGURE 2.

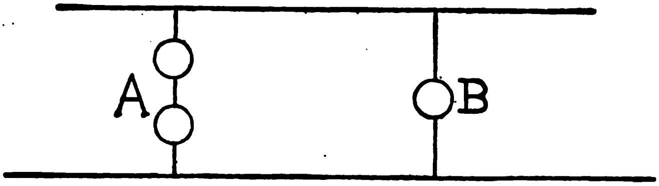


FIGURE 3.

lamps, and will receive but half the current of the single lamp. In Fig. 4 we have still another arrangement. The lamp A limits the current which can flow through B and C, and that current which does flow

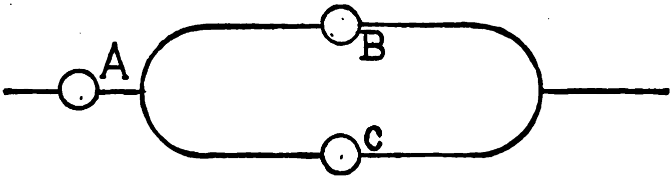


FIGURE 4.

divides between B and C in proportion to their conductivities. If B has a resistance of 110 ohms and C 220 ohms, then B will carry two parts of the current and C only one. The combined resistance of all lamps, Fig. 2, equals the resistance of one lamp divided by the number of lamps. The combined resistance, Fig. 3, equals the sum of the resistances of the two lamps at A multiplied by the resistance of B and divided by the sum of all the resistances. If the resistance of each of the lamps were 110 ohms, the problem would work out thus: $\frac{110+110\times110}{110+110+110}=73\frac{1}{3}$.

In Fig. 4 the total resistance is $\frac{110\times220}{110+220}+110=183\frac{1}{3}$.

One practical illustration of the above law may be found in the method of switching series arc lamps,

Fig. 5. As long as the switch S is open the arc lamp burns, but as soon as the switch is closed the lamp is

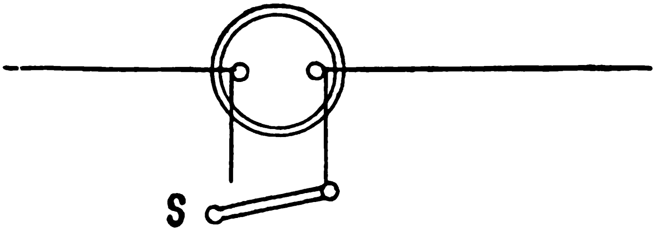


FIGURE 5.

extinguished because the resistance of the short wire and the switch S is so much less than that of the arc lamp that practically all the current flows through S.

CHAPTER II

WIRING SYSTEMS — CALCULATION OF WIRES — WIRING TABLES.

Wiring Systems. The system of wiring which is most generally used for incandescent lighting and ordinary power purposes is called the two wire parallel system. In this system of wiring the two wires run side by side, one of them being the positive and one the negative. The lamps, motors and other devices are then connected from one wire to the other. A constant pressure of electricity is maintained between the two wires, and the number and size of lamps, or other apparatus, connected to these two wires, determine how many amperes are required. Each lamp or motor is independent of the others and may be turned on or off without disturbing the others.

A diagram of such a system is shown in Fig. 6.

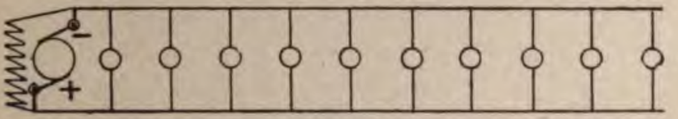


FIGURE 6.

In this system the quantity of current varies in proportion to the number of devices connected to it. Suppose that we are maintaining a pressure or potential or electromotive force of 110 volts on such a system, and that we have connected to the system ten 16 candle power incandescent lamps, consuming one-half ampere each. The total quantity of current to supply these lamps would be 5 amperes. If we should now switch on ten more lamps the quantity of current would be 10 amperes, and the pressure would remain 110 volts. This system is also known as the "constant potential system," or multiple arc system, and among the numerous devices used in connection with it are the constant potential arc lamp, the shunt motor, the compound wound motor, the series motor, incandescent lamps, etc. Electric street railways are also operated on this system. The electricity supplied through this system of wiring may be either direct or alternating current.

The series arc system, Fig. 7, is a loop; the greatest electrical pressure being at the terminal or terminal ends of the loop. The current in such a system of wiring is constant, and the pressure varies as the lamps or other apparatus are inserted in or cut out of the circuit. This system is also called the constant current system. The same current passes through all of the lamps, and the different lamps are also independent of each other.

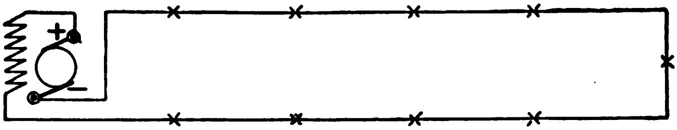


FIGURE 7.

At the present time the series system is used mostly for operating high tension series arc lamps. The use of motors with it has been almost entirely abandoned.

The series multiple system, Fig. 8, is simply a number of multiple systems placed in series. This method of wiring was at one time employed to run incandescent lights from a high tension series arc light circuit, but on account of the danger connected with the use of incandescent lamps, operated from a high tension arc lamp circuit, the system has been abandoned. It is not approved by insurance companies, and consequently is not often used.

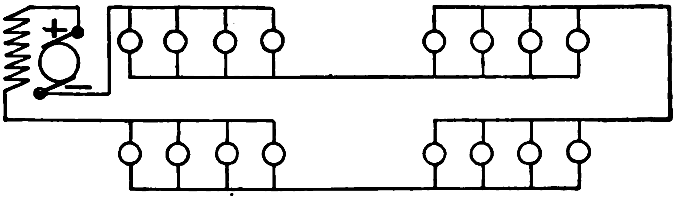


FIGURE 8.

The multiple series system consists of a number of small series circuits, connected in multiple, as shown in Fig. 9. This system of wiring is used on constant potential systems, where the voltage is much greater than is required by the apparatus to be used, as, for instance, connecting eleven miniature lamps, whose individual pressure required is 10 volts, into a series, and then connecting the extreme ends of such a series to a multiple circuit whose pressure is 110 volts. In electric street cars, where the pressure between the

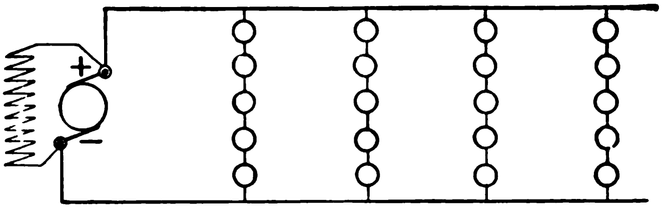


FIGURE 9.

trolley wire and the running rail is 550 volts, it will be noticed that the lighting circuits in the car consist of five 110 volt lamps in series, and one end of this series is connected to the trolley line, the other end being grounded on the trucks.

The three wire system. Fig. 21, is a system of multiple series. In this system, as its name implies, three wires are used, connected up to the machines in

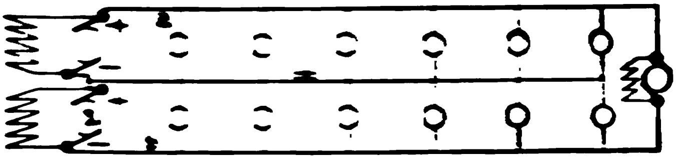


FIGURE 21.

the manner shown in the diagram. Both machines are in series when all lights are turned on, but should all lights on one side of the neutral or center wire be turned off the machine on the other side alone would run the other lights.

One of these wires is positive, the other is negative, and the remaining one or center wire is neutral. In ordinary practice from positive to negative wire, a potential of 220 volts is maintained, while from the neutral wire to either of the outside wires a potential of 110 volts exists. The advantages of such a system are many, principally among them is the use of double the voltage of the two wire system; this reduces the current one-half and allows the use of smaller wires. This system only requires three wires for the same amount of current that would require four in the other system. Motors are supplied at 220 volts, while lights operate at 110. Incandescent lighting circuits can be maintained from either outside wire to the neutral wire. The saving in copper by dispensing with the fourth wire is not the only advantage in the saving of conductors. The neutral wire may be much smaller than the outside wires because it will seldom be called upon to carry much current.

Inside of buildings, however, where overheating of a wire is always dangerous, the neutral wire should be of the same size as the others. By tracing out the circuits in Fig. 10, it will readily be seen that, so long as all lamps are burning, the current passes out of dynamo 1 into the positive wire and from there through the lamps (always two in series) to the negative or – wire, returning over it to the – pole of dynamo 2. So long as an equal number of lamps is burning on each side of the neutral, no current passes over the neutral wire in either direction. But if the positive or + wire should be broken, say at *a*, dynamo 1 will no longer send current and the lamps between the positive and neutral wire will be out.

Dynamo 2 will now supply the lamps between the neutral and the negative wire and for the time being the neutral wire will become positive. Should the negative wire break at *b*, the lamps connected to it would be out and dynamo 1 would supply the lights on its side, the neutral wire becoming negative. When motors of one or more H. P. are used on this system, it is usual to connect them to the outside wires using 220 volts. It is important also to arrange the wiring so that an equal number of lights are installed on each side of the neutral. When the lights and motors are so arranged, the system is said to be "balanced." It is also very important to arrange so that the neutral wire cannot readily be broken. Should the neutral wire be opened while, for instance, fifty lamps were burning on one side and say ten or twenty on the other, the ten or twenty would be broken by the excess voltage. Grounded wires ordinarily cause more trouble than anything else on electric light or power circuits. But with the three wire system, the neutral wire is often grounded. Grounds on this wire are less important than on outer wires, because it carries very little current and that current is constantly varying in direction so that no great amount of electrolysis can occur at any one place. For full descriptions and drawings of methods of wiring, see *Wiring Diagrams and Descriptions*, by Horstmann and Tousley, published by Frederick J. Drake & Co., Chicago.

Feeders (see Fig. 11), as the name implies, is a term used for the main wires which convey the current to

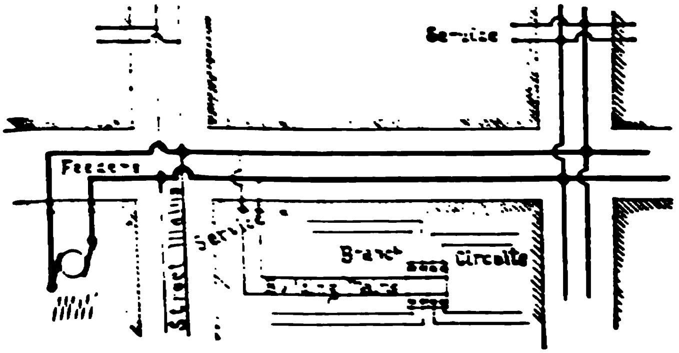


FIGURE 11.

any number of other wires, and the feeders become a part of the multiple series, multiple and three wire systems.

Distributing mains are the wires from which the wires entering buildings receive their supply.

Service wires are the wires that enter the buildings.

The center of distribution is a term used for that part of the wiring system from which a number of branch circuits are fed by feeder wires. In most buildings the tap lines are all brought to one point, and terminate in cut-out boxes. These cut-out boxes are supplied by the main. Each floor of the building may have a cut-out box, or each floor of the building may have several cut-out boxes of the above description.

Calculation of Wires. If we desire to transmit or deliver a certain quantity of liquid through a pipe, we estimate the size of the pipe and the comparison of sizes in the pipes by squaring the diameter, in inches, and multiplying the result by the standard fraction .7854. By way of explanation we will dwell upon the above method for a short time. In Fig. 12 we have a surface which measures one inch on all four sides, and which has an area of one square inch.

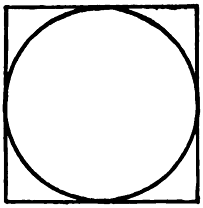


FIGURE 12.

Now in a circle which is contained in this figure, and which touches all four sides of the square, we would only have .7854 of a square inch. If the diameter of this circle is 2 in., instead of 1, you can readily see by Fig. 13 that its area is four times as great or 2 × 2 = 4. We then multiply by the standard number .7854 in order to find the area contained in the two-inch circle; and if the diameter were 3 in., then 3 × 3 = 9, and 9 × .7854 would be the area in square inches contained in the three-inch circle.

Again, if we had a square one inch in area, like Fig. 14, and we took one leg of a carpenter's compass and placed it on one corner of this square, striking a quarter-circle from one adjacent corner to the other adjacent corner, the area inscribed by the compass would again be .7854 of a square inch.

The above will explain to the reader the relation between the circular and square mil. The circular mil is a circle one mil ($\frac{1}{1000}$ of an inch) in diameter. The square mil is a square one mil long on each side. In the calculation of wires for electrical purposes, the circular mil is generally used, because we need only multiply the diameter of a wire by itself to obtain its area in circular mils. If we used square mils we should have to multiply by .7854.

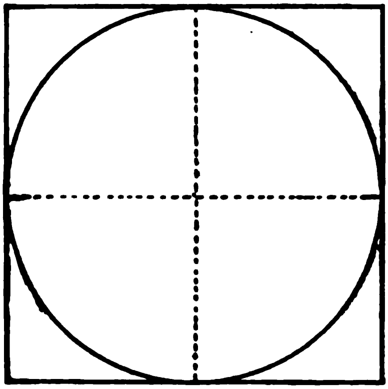


FIGURE 13.

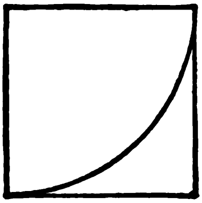


FIGURE 14.

The resistance of a conductor (wire) increases directly as its length, and decreases directly as its diameter is increased. A wire having a diameter of one mil and being one foot long has a resistance at ordinary temperature of 10.7 ohms. If this wire were two feet long, it would have a resistance of 21.4 ohms, but if it were two mils in diameter and one foot long, it would have a resistance one-fourth of 10.7, or about 2.67.

Every transmission of electrical energy is accompanied by a certain loss. We can never entirely prevent this loss any more than we can entirely avoid friction. But we can reduce our loss to a very small quantity simply by selecting a very large wire to carry the current. This would be the proper thing to do if it were not for the cost of copper, which would make such an installation very expensive. As it is, wires are usually figured at a loss of from 2 to 5 per cent.

The greater the loss of energy we allow in the wires the smaller will be the cost of wire, since we can use smaller wires with the greater loss.

In long distance transmission and where the quality of light is not very important, a loss of 10 or 20 per cent. is sometimes allowed, but in stores, residences, etc., the loss should not exceed 2 or 3 per cent., otherwise the candle power of the lamps will vary too much.

Where the cost of fuel is high the saving in first cost of copper is soon offset by the continuous extra cost of fuel to make up for the losses in the wires.

To determine the size of wire necessary to carry a certain current at a given number of volts loss, we may proceed in the following manner: Multiply the number of feet of wire in the circuit by the constant 10.7, and it will give the circular mils necessary for one ohm of resistance. Multiply this by the amperes, and this will give the circular mils for a loss of one volt. Divide this last result by the volts to be lost, and the answer will be the number of circular mils diameter that a copper wire must have to carry the current with such a loss. After obtaining the number of circular mils required, refer to the table of circular mils, and select the wire having such a number of circular mils.

The formula is as follows:

$$\frac{\text{Feet of wire} \times 10.7 \times \text{amperes}}{\text{Volts lost}} = \text{circular mils.}$$

By simply transposing the above terms we obtain another formula, which can be used to determine the volts lost in a given length of wire of a certain size, carrying a certain number of amperes.

The formula is as follows:

$$\frac{\text{Feet of wire} \times 10.7 \times \text{amperes}}{\text{Circular mils}} = \text{Volts lost.}$$

And again, by another change in the terms we obtain a formula which shows the number of amperes that a wire of given size and length will carry at a given number of volts lost:

$$\frac{\text{Circular mils} \times \text{volts lost}}{\text{Feet of wire} \times 10.7} = \text{Amperes.}$$

In computing the necessary size of a service or main wire, to supply current for either lamps or motors, it is necessary to know the exact number of feet from the source of supply to the center of distribution. When the distance of center of distribution is given it is well to ascertain whether it is the true center or not. It may be only the distance from a cut-out box that has been given, when it should have been the distance from the point at which the service enters the building or, perhaps, from the point at which the service is connected to the street mains. For when the size is determined it is for a certain loss which is distributed over the entire length of the wire to be installed. The transmission of additional current on the mains in the building increases the drop in volts in the main, and likewise in the service. Most buildings are wired for a certain per cent loss in voltage, estimated from the point where the service enters the building. All additions should be estimated from that point.

In using the formula for finding the proper size wire to carry current, the first thing to be determined is the length of the wire; remember that the two wires are in parallel, and therefore the total length of the wire is twice the total distance from the commencement to the end of the circuit. If the proposed load on this circuit is given in lamps, you may reduce it to amperes, and if the proposed load is given in horsepower, you may reduce it to amperes. The voltage on the circuit is known in either case. You take the loss of the voltage and divide the product of amperes, multiplied by the length, as found, and 10.7 by it; this answer will be the size in circular mils of a wire necessary to carry the amperes.

Example: What is the size of wire required for a 50 volt system, having 100 lamps at a distance of 100 ft., with a 4 per cent loss?

Answer: The load of 100 lamps on a 50 volt system is 100 amperes, and a 4 per cent loss of 50 volts is 2 volts. Multiply the total length of the wire, which is twice the distance, or 200 ft., by the 100 amperes of current; this gives us 20,000. Then multiply this by the constant, which is 10.7; this gives us 214,000. Divide this by 2, which is the loss in volts, and you have 107,000 circular mils diameter of wire required

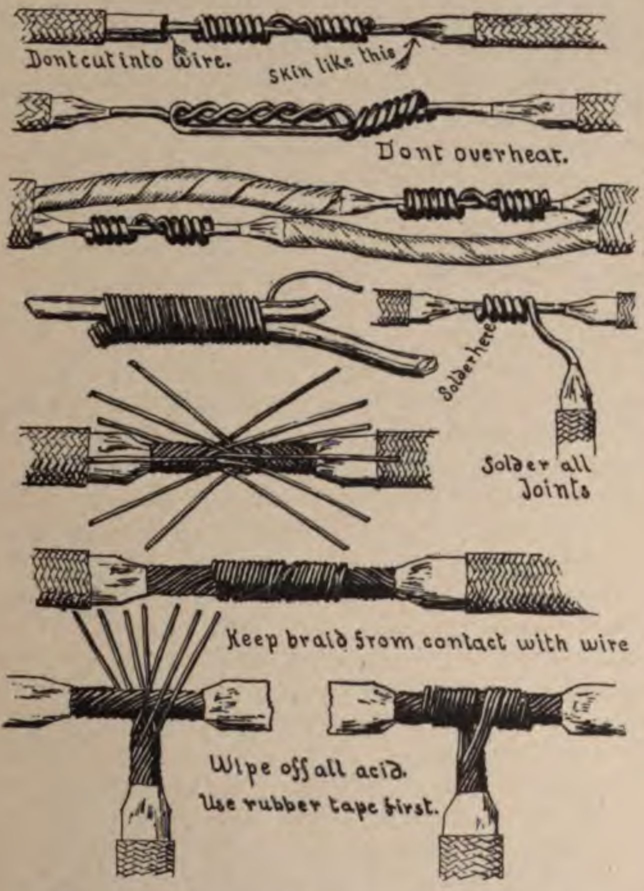
When determining the size of wire to be used it is always necessary to consult the table of carrying capacities, and this will very often indicate a wire much larger than that determined by the wiring formula, especially if a somewhat high loss is figured on.

When estimating the distance it is not always correct to take the total distance.

To illustrate: Suppose one lamp is 100 ft. from the point at which the distance is determined, and the farthest lamp is 400 ft., the remaining lamps being distributed evenly between these two points; we would average the distances between the first and last lamp, which would be 200 ft. It is necessary to use judgment in estimating the mean or average distance, as the lamps or motors are bunched differently in each case

In a series system the loss in voltage makes considerable difference to the power, but does not affect the quality of the light as much as in a multiple arc or parallel system. In a parallel system the lamps require a uniform pressure, and this can only be had by keeping the loss low. In a series system the lamps depend upon the constant current and the voltage varies with the resistance, in order to keep the current constant. This is accomplished by a regulator on the dynamo, which is designed to compensate for the changes of resistance in the circuit and to increase or decrease the pressure as required.

In estimating the size of wire for a series system you consider the total length of the loop. There is no average distance as the total current travels over the entire circuit. We will assume that you have an arc light circuit of a No. 6 Brown & Sharp gauge wire and want to find what loss there is in this circuit. You have the area of a No. 6 wire, which is 26,250 circular mils, and the length of the circuit, and from this we will figure the loss in this manner: Assuming the circuit to be 10,000 ft. long, and the current 10 amperes, we will multiply 10,000 ft. by 10 amperes, and this by 1.07, which gives us 1,070,000, and divide this by 26,250. The answer is 40 volts, lost in the circuit.



Such a circuit would operate at perhaps 2,000 or 3,000 volts, and a loss of 40 volts would not be excessize. It would be wasting a little less energy than is required to burn one large arc lamp.

The *multiple series system* is a number of small wires connected in multiple, and is the same as the multiple arc or parallel system. The wire is figured in the same way as for the multiple arc system.

The *series multiple system* is a number of small parallel systems, and these are connected in series by the main wire. The wire is figured the same as for the series system.

The *Edison three-wire system* is a double multiple, and the two outside wires are the ones considered when carrying capacity is figured. When this system is under full load or balanced, the neutral wire does not carry any current, but the blowing of a fuse in one of the outside wires may force the neutral wire to carry as much current as the outside wire and it should, therefore, be of the same size. The amount of copper needed with this system is only three-eighths of that required for a two-wire system.

Wiring Tables. On the following pages are presented wiring tables for 110, 220 and 500 volt work. These tables are used in the following manner: Suppose we wish to transmit 60 amperes a distance of 1,800 ft. at 110 volts and at a loss of 5 per cent. We take the column headed by 60 in the top row and follow it downward until we come to 1,800, or the number nearest to it. From this number we now follow horizontally to the left, and under the column headed by 5 we find the proper size of wire, which is 500,000 c. m. The same current, at a loss of 10, would require only a 0000 wire, as indicated under the column at the left, headed by 10.

Before making selection of wire, always consult the table of carrying capacities, page 38. This table is taken from the rules of the National Board of Fire Underwriters, and is in general use.

The first three of the following tables are wiring tables for the three standard voltages, 110, 220, 500 From these tables can be found the sizes of wire required to carry various amounts of current (in amperes) different distances (in feet) at several percentages of loss, or the distance the different sizes of wire will carry various amounts of current at several percentages of loss can be found.

These tables are figured on safe carrying capacity for the different sizes of wire. The distances in feet are to the center of distribution.

110-VOLT WIRING TABLE.

Top Figures in Each Column the Percentage of Loss; Those Below the Size of Wire B. & S. Gauge.						The Top Figures in Each Column are the Number of Amperes; Those Below the Distance in Feet.																		
2	**3.15**	**5**	**6.3**	**8**	**10**	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**	**40**	**50**	**60**	**80**	**100**	**125**	**150**	**200**	**250**	**300**	**350**
......	......	......	......	......	500000	127315	63657	42438	25463	16975	12731	10185	8487	6365	5092	4243	3182	2546	2037	1697	1273	1018	849	727
......	......	......	......	500000	400000	101850	50925	33950	20370	13580	10185	8148	6790	5092	4074	3395	2546	2037	1629	1358	1018	815	679	......
......	......	......	500000	400000	300000	76380	38190	25460	15276	10184	7638	6111	5092	3819	3055	2546	1910	1527	1222	1018	763	611	......	......
......	......	500000	400000	300000	0000	53880	26940	17960	10776	7184	5388	4311	3592	2694	2155	1796	1347	1077	862	718	538	......	......	......
......	......	400000	300000	0000	000	40410	20205	13470	8082	5498	4041	3233	2744	2020	1616	1372	1010	808	647	538	......	......	......	......
......	500000	300000	0000	000	00	33885	16942	11295	6777	4517	3388	2711	2258	1694	1355	1129	822	677	542	452	......	......	......	......
......	400000	0000	000	00	0	26880	13440	8960	5377	3584	2688	2151	1792	1344	1075	896	672	537	430	......	......	......	......	......
500000	300000	000	00	0	1	21310	10655	7103	4262	2841	2131	1705	1420	1065	852	710	532	426	341	......	......	......	......	......
400000	0000	00	0	1	2	16900	8450	5633	3380	2253	1690	1352	1126	845	676	563	422	338	......	......	......	......	......	......
300000	000	0	1	2	3	13400	6700	4466	2680	1786	1340	1072	893	670	536	447	335	......	......	......	......	......	......	......
0000	00	1	2	3	4	10605	5302	3535	2121	1413	1060	848	706	530	424	353	......	......	......	......	......	......	......	......
000	0	2	3	4	5	8430	4215	2810	1686	1124	843	675	562	422	337	281	......	......	......	......	......	......	......	......
00	1	3	4	5	6	6685	3342	2228	1337	890	668	535	445	334	267	......	......	......	......	......	......	......	......	......
0	2	4	5	6	7	5300	2650	1766	1060	706	530	424	353	265	212	......	......	......	......	......	......	......	......	......
1	3	5	6	7	8	4220	2110	1406	844	562	422	338	281	211	......	......	......	......	......	......	......	......	......	......
2	4	6	7	8	9	3330	1665	1110	666	444	333	266	222	......	......	......	......	......	......	......	......	......	......	......
3	5	7	8	9	10	2640	1320	880	528	352	264	211	......	......	......	......	......	......	......	......	......	......	......	......
4	6	8	9	10	11	2095	1047	698	419	278	209	......	......	......	......	......	......	......	......	......	......	......	......	......
5	7	9	10	11	12	1660	830	553	333	221	......	......	......	......	......	......	......	......	......	......	......	......	......	......
6	8	10	11	12	13	1320	660	440	264	176	......	......	......	......	......	......	......	......	......	......	......	......	......	......
7	9	11	12	13	14	1045	522	348	209	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
8	10	12	13	14	15	830	415	276	166	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
9	11	13	14	15	16	655	327	218	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
10	12	14	15	16	......	525	263	175	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
11	13	15	16	......	......	412	206	137	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
12	14	16	......	......	......	330	165	111	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
13	15	......	......	......	......	263	131	87	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
14	16	......	......	......	......	206	103	68	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
15	......	......	......	......	......	165	82	55	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
16	......	......	......	......	......	131	65	43	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

One 16-Candlepower 55 Watt Incandescent Lamp=½ ampere. One Horsepower= 6.78 amperes. One 2000-Candlepower Constant Potential Arc Lamp=5 amperes.

220-VOLT WIRING TABLE.

Top Figures in Each Column the Percentage of Loss; Those Below the Size of Wire B. & S. Gauge.						The Top Figures in Each Column are the number of Amperes: Those Below the Distance in Feet.																		
2	**3.15**	**5**	**6.3**	**8**	**10**	**2**	**4**	**6**	**10**	**15**	**20**	**25**	**30**	**40**	**50**	**60**	**80**	**100**	**120**	**160**	**200**	**250**	**300**	**350**
......	......	......	......	......	500000	254630	127315	84877	50926	33950	25463	20370	16975	12731	10185	8487	6366	5092	4243	3183	2546	2037	1697	145
......	......	......	......	500000	400000	203700	101850	67900	40740	27160	20370	16295	13580	10185	8147	6790	5092	4073	3395	2546	2036	1629	1357	
......	......	......	500000	400000	300000	152775	76387	50924	30550	20370	15275	12222	10183	7637	6111	5091	3819	3055	2546	1910	1528	1222	....	....
......	......	500000	400000	300000	0000	107780	53890	35926	21556	14370	10778	8622	7185	5389	4311	3592	2695	2155	1796	1348	1077	....	....	....
......	......	400000	300000	0000	000	85450	42725	28483	17090	11393	8545	6836	5696	4272	3418	2848	2136	1709	1424	1068	....	....	....	....
......	500000	300000	0000	000	00	67745	33872	22581	13549	9032	6774	5420	4516	3387	2710	2258	1679	1355	1129	839	....	....	....	....
......	400000	0000	000	00	0	53770	26885	17923	10754	7170	5377	4302	3585	2688	2151	1792	1344	1075	896	....	....	....	....	....
500000	300000	000	00	0	1	42620	21310	14206	8524	5682	4262	3410	2841	2131	1705	1420	1065	852	710	....	....	....	....	....
400000	0000	00	0	1	2	34055	17027	11351	6811	4540	3405	2724	2270	1702	1362	1135	851	681	....	....	....	....	....	....
300000	000	0	1	2	3	26570	13285	8856	5314	3542	2657	2125	1771	1328	1062	885	664	....	....	....	....	....	....	....
0000	00	1	2	3	4	21255	10627	7085	4251	2834	2125	1700	1417	1062	850	708	....	....	....	....	....	....	....	....
000	0	2	3	4	5	16855	8427	5618	3371	2247	1685	1348	1123	842	614	562	....	....	....	....	....	....	....	....
00	1	3	4	5	6	13365	6682	4455	2673	1782	1336	1050	891	668	525	....	....	....	....	....	....	....	....	....
0	2	4	5	6	7	10560	5280	3520	2112	1413	1060	848	706	530	424	....	....	....	....	....	....	....	....	....
1	3	5	6	7	8	8405	4202	2801	1681	1120	840	672	560	420	......	....	....	....	....	....	....	....	....	....
2	4	6	7	8	9	6665	3332	2221	1333	888	666	533	444	......	......	....	....	....	....	....	....	....	....	....
3	5	7	8	9	10	5275	2637	1758	1055	703	527	422	......	......	......	....	....	....	....	....	....	....	....	....
4	6	8	9	10	11	4190	2095	1396	838	558	419	......	......	......	......	....	....	....	....	....	....	....	....	....
5	7	9	10	11	12	3325	1662	1108	665	443	......	......	......	......	......	....	....	....	....	....	....	....	....	....
6	8	10	11	12	13	2635	1317	878	527	351	......	......	......	......	......	....	....	....	....	....	....	....	....	....
7	9	11	12	13	14	2090	1045	696	418	......	......	......	......	......	......	....	....	....	....	....	....	....	....	....
8	10	12	13	14	15	1655	827	551	331	......	......	......	......	......	......	....	....	....	....	....	....	....	....	....
9	11	13	14	15	16	1315	657	438	......	......	......	......	......	......	......	....	....	....	....	....	....	....	....	....
10	12	14	15	16	......	1050	525	350	......	......	......	......	......	......	......	....	....	....	....	....	....	....	....	....
11	13	15	16	......	......	828	414	276	......	......	......	......	......	......	......	....	....	....	....	....	....	....	....	....
12	14	16	......	......	......	657	328	219	......	......	......	......	......	......	......	....	....	....	....	....	....	....	....	....
13	15	...	......	......	......	526	263	175	......	......	......	......	......	......	......	....	....	....	....	....	....	....	....	....
14	16		......	......	......	414	207	138	......	......	......	......	......	......	......	....	....	....	....	....	....	....	....	....
15	......	......	......	......	......	329	164	109	......	......	......	......	......	......	......	....	....	....	....	....	....	....	....	....
16	......	......	......	......	......	265	132	88		......	......	......	......	......	......	....	....	....	....	....	....	....	....	....

One 16-Candlepower 55 Watt Incandescent Lamp=¼ ampere. One Horsepower=3.39 amperes. One 2000-Candlepower Constant Potential Arc Lamp=2½ amperes.

500-VOLT WIRING TABLE.

Top Figures in Each Column the Percentage of Loss; Those Below the Size of Wire B. & S. Gauge.						The Top Figures in Each Column are the Number of Amperes: Those Below the Distance in Feet.																
2	3.15	5	6.3	8	10	2	4	6	10	15	20	25	30	40	50	60	80	100	120	150	170	200
......	......	......	......		500000	578700	289350	192900	115740	77160	57870	46296	38580	28935	23148	19290	14467	11574	9645	7716	6800	5787
......	......	......	......	500000	400000	460645	230322	153550	92129	61420	46064	36852	30710	23032	18426	15355	11516	9213	7677	6142	5420	4606
......	......	......	500000	400000	300000	347220	173610	115740	69444	45296	34722	27777	22648	17361	13888	11324	8680	6944	5662	4629	4085	3472
......	......	500000	400000	300000	0000	244950	122475	81650	48990	32660	24495	19595	16330	12247	9797	8165	6123	4898	4082	3266	2882	2449
......	......	400000	300000	0000	000	194215	97107	64738	38843	25895	19421	15537	12947	9710	7768	6473	4855	3884	3236	2589	2285	......
......	500000	300000	0000	000	00	154025	77012	51341	30805	20536	15402	12322	10268	7701	6161	5134	3850	3080	2567	2054	......	......
......	400000	0000	000	00	0	122210	61105	40736	24442	16293	12221	9775	8146	6110	4887	4073	3055	2443	2036	......	......	......
500000	300000	000	00	0	1	96405	48202	32135	19281	12854	9640	7712	6427	4820	3856	3213	2410	1928	1606	......	......	......
400000	0000	00	0	1	2	76565	38282	25521	15313	10208	7656	6125	5104	3828	3062	2552	1914	1531	......	......	......	......
300000	000	0	1	2	3	60915	30457	20305	12183	8122	6091	4873	4061	3045	2436	2030	1522	......	......	......	......	......
0000	00	1	2	3	4	48310	24155	16103	9662	6441	4831	3864	3220	2415	1932	1610	......	......	......	......	......	......
000	0	2	3	4	5	38282	19140	12760	7656	5104	3828	3062	2552	1914	1531	1276	......	......	......	......	......	......
00	1	3	4	5	6	30457	15228	10152	6091	4061	3045	2436	2030	1522	1218	......	......	......	......	......	......	......
0	2	4	5	6	7	24155	12077	8051	4831	3220	2415	1932	1610	1207	966	......	......	......	......	......	......	......
1	3	5	6	7	8	19140	9570	6380	3828	2552	1914	1531	1276	957	......	......	......	......	......	......	......	......
2	4	6	7	8	9	15229	7614	5076	3045	2030	1522	1218	1015	......	......	......	......	......	......	......	......	......
3	5	7	8	9	10	12077	6039	4026	2415	1610	1207	978	......	......	......	......	......	......	......	......	......	......
4	6	8	9	10	11	9570	4785	3190	1914	1276	957	......	......	......	......	......	......	......	......	......	......	......
5	7	9	10	11	12	7639	3819	2546	1527	1018	......	......	......	......	......	......	......	......	......	......	......	......
6	8	10	11	12	13	6039	3019	2013	1207	805	......	......	......	......	......	......	......	......	......	......	......	......
7	9	11	12	13	14	4785	2392	1595	957	......	......	......	......	......	......	......	......	......	......	......	......	......
8	10	12	13	14	15	3819	1910	1273	763	......	......	......	......	......	......	......	......	......	......	......	......	......
9	11	13	14	15	16	3019	1510	1005	......	......	......	......	......	......	......	......	......	......	......	......	......	......
10	12	14	15	16	......	2392	1195	797	......	......	......	......	......	......	......	......	......	......	......	......	......	......
11	13	15	16	......	......	1910	950	636	......	......	......	......	......	......	......	......	......	......	......	......	......	......
12	14	16	......	......	......	1510	755	503	......	......	......	......	......	......	......	......	......	......	......	......	......	......
13	15	......	......	......	......	1195	597	398	......	......	......	......	......	......	......	......	......	......	......	......	......	......
14	16	......	......	......	......	950	475	316	......	......	......	......	......	......	......	......	......	......	......	......	......	......
15	......	......	......	......	......	755	377	252	......	......	......	......	......	......	......	......	......	......	......	......	......	......
16	......	......	......	......	......	597	298	199	......	......	......	......	......	......	......	......	......	......	......	......	......	......

One Horsepower = 1.49 amperes. When lights are used the lamps are put in series.

TABLE OF SIZES, MEASUREMENTS, WEIGHTS, ETC., OF COPPER WIRE.

Size B. & S. Gauge	Diam. Mils	AREA		WEATHER-PROOF WIRE						BARE WIRE			RESISTANCE AT 75° F.			
				Double Braided			Triple Braided									
		Circular Mils	Square Mils	Pounds per 1000 feet	Pounds per mile	Feet per Pound	Pounds per 1000 feet	Pounds per Mile	Feet per Pound	Pounds per 1000 feet	Pounds per Mile	Feet per Pound	R Ohms per 1000 feet	Ohms per Mile	Feet per Ohm	Ohms per Pound
....	707 160	500000 0	392700	1680	8870	59	1744	9208	57	1562	8247	64	02079	10978	48290	00001322
....	632 455	400000 0	314160	1343	7091	74	1405	7418	76	1209	6489	81	02589	13723	38630	00002063
....	547 722	300000 0	235620	1055	5570	94	1112	5873	90	941	4968	1 06	03465	18297	28980	00003656
0000	460 000	211600 0	166190	700	3718	1 42	746	3940	1 34	639 33	3375 7	1 56	04904	25891	20392 9	00007653
000	409 640	167805 0	131790	565	2983	1 77	599	3161	1 67	507 01	2677 0	1 97	06181	32649	16172 1	00012169
00	364 800	133079 0	104520	460	2433	2 17	493	2600	2 03	402 09	2123 0	2 49	07797	41168	12825 4	00019438
0	324 950	105592 5	82887	371	1963	2 69	397	2095	2 52	319 04	1684 6	3 14	09827	51885	10176 4	00030734
1	289 300	83694 5	65733	281	1483	3 56	299	1572	3 35	252 88	1335 2	3 95	12398	65460	8066 0	00048920
2	257 630	66373 2	52130	231	1219	4 33	248	1310	4 03	200 54	1058 8	4 99	15633	82543	6396 7	00077784
3	229 420	52633 5	41339	193	1018	5 18	207	1091	4 84	159 03	839 68	6 29	19714	1 04090	5072 5	0012370
4	204 310	41742 6	32784	152	802	6 58	162	855	6 17	126 12	665 91	7 93	24858	1 31248	4022 9	0019666
5	181 940	33102 2	25998	123	650	8 12	134	710	7 45	100 01	528 05	10 00	31346	1 65507	3190 2	0031273
6	162 020	26250 5	20617	104	550	9 60	112	595	8 87	79 32	418 81	12 61	39528	2 08706	2529 9	0049723
7	144 280	20816 7	16349	......	......	......	......	......	......	62 90	332 11	15 90	49845	2 63184	2006 2	0079078
8	128 490	16509 7	12966	66	352	15 00	74	387	13 65	49 88	263 37	20 05	62849	3 31843	1591 1	0125719
9	114 430	13094 2	10284	......	......	......	......	......	......	39 56	208 88	25 28	79242	4 18400	1262 0	0199853
10	101 890	10381 6	8153 2	48	250	21 11	52	271	19 50	31 37	165 63	31 38	99948	5 27726	1000 5	0317946
11	90 742	8231 11	6467 0	......	......	......	......	......	......	24 88	137 37	40 20	1 2692	6 65357	793 56	0505413
12	80 808	6529 94	5128 6	31	160	33 00	33	172	30 36	19 73	104 18	50 69	1 5890	8 39001	629 82	0803641
13	71 961	5178 39	4067 1	......	......	......	......	......	......	15 65	82 632	63 91	2 0047	10 5798	499 06	127788
14	64 084	4106 76	3225 4	23	118	44 74	24	125	42 24	12 41	65 525	80 38	2 5266	13 3405	395 79	203180
15	57 068	3256 76	2557 8	......	......	......	......	......	......	9 84	51 956	101 63	3 1860	16 8223	313 87	323079
16	50 820	2582 67	2028 6	14	76	69 47	15	80	66 00	7 81	41 237	128 14	4 0176	21 2130	248 90	513737

TABLE OF CARRYING CAPACITY OF WIRES.

UNDERWRITERS' RULES.

B. & S. G.	Table A. Rubber Insulation. Amperes.	Table B. Other Insulations. Amperes.	Circular Mils.
18	3	5	1,624
16	6	8	2,583
14	12	16	4,107
12	17	23	6,530
10	24	32	10,380
8	33	46	16,510
6	46	65	26,250
5	54	77	33,100
4	65	92	41,740
3	76	110	52,630
2	90	131	66,370
1	107	156	83,690
0	127	185	105,500
00	150	220	133,100
000	177	262	167,800
0000	210	312	211,600
Circular Mils.			
200,000	200	300	
300,000	270	400	
400,000	330	500	
500,000	390	590	
600,000	450	680	
700,000	500	760	
800,000	550	840	
900,000	600	920	
1,000,000	650	1,000	
1,100,000	690	1,080	
1,200,000	730	1,150	
1,300,000	770	1,220	
1,400,000	810	1,290	
1,500,000	850	1,360	
1,600,000	890	1,430	
1,700,000	930	1,490	
1,800,000	970	1,550	
1,900,000	1,010	1,610	
2,000,000	1,050	1,670	

The lower limit is specified for rubber-covered wires to prevent gradual deterioration of the high insulations by the heat of the wires, but not from fear of igniting the insulation. The question of drop is not taken into consideration in the above tables.

TABLE OF DIMENSIONS OF PURE COPPER WIRE.*

No. B. & S.	Diam. Mils.	Area.		Weight and Length. Sp. Gr. 8.9.		
		Circular Mils.	Square Mils.	Lbs. per 1000 feet.	Lbs. per Mile.	Feet per Pound.
0000	460.000	211600.0	166190.2	640.73	3383.04	1.56
000	409.640	167805.0	131793.7	508.12	2682.85	1.97
00	364.800	133079.0	104520.0	402.97	2127.66	2.48
0	324.950	105592.5	82932.2	319.74	1688.20	3.13
1	289.300	83694.5	65733.5	253.43	1338.10	3.95
2	257.630	66373.2	52129.4	200.98	1061.17	4.98
3	229.420	52633.5	41338.3	159.38	841.50	6.28
4	204.310	41742.6	32784.5	126.40	667.38	7.91
5	181.940	33102 2	25998.4	100.23	529.23	9.98
6	162.020	26250.5	20617.1	79.49	419.69	12.58
7	144.280	20816.7	16349.4	63.03	332.82	15.86
8	128.490	16509.7	12966.7	49.99	263.96	20.00
9	114.430	13094.2	10284.2	39.65	209.35	25.22
10	101.890	10381.6	8153.67	31.44	165.98	31.81
11	90.742	8234.11	6467.06	24.93	137.65	40.11
12	80.808	6529.94	5128.60	19.77	104.40	50.58
13	71.961	5178.39	4067.07	15.68	82.792	63.78
14	64.084	4106.76	3225.44	12.44	65.658	80.42
15	57.068	3256.76	2557.85	9.86	52.069	101.40
16	50.820	2582.67	2028.43	7.82	41.292	127.87
17	45.257	2048.20	1608.65	6.20	32.746	161.24
18	40.303	1624.33	1275.75	4.92	25.970	203.31
19	35.890	1288.09	1011.66	3.90	20.594	256.39
20	31.961	1021.44	802.24	3.09	16.331	323.32
21	28.462	810.09	636.24	2.45	12.952	407.67
22	25.347	642.47	504.60	1.95	10.272	514.03
23	22.571	509.45	400.12	1.54	8.1450	648.25
24	20.100	404.01	317.31	1.22	6.4593	817.43
25	17.900	320.41	251.65	.97	5.1227	1030.71
26	15.940	254.08	199.56	.77	4.0623	1299.77
27	14.195	201.50	158.26	.61	3.2215	1638.97
28	12.641	159.80	125.50	.48	2.5548	2066.71
29	11.257	126.72	99.526	.38	2.0260	2606.13
30	10.025	100.50	78.933	.30	1.6068	3286.04
31	8.928	79.71	62.603	.24	1.2744	4143.18
32	7.950	63.20	49.639	.19	1.0105	5225.26
33	7.080	50.13	39.360	.15	.8015	6588.33
34	6.304	39.74	31.212	.12	.6354	8310.17
35	5.614	31.52	24.753	.10	.5039	10478.46
36	5.000	25.00	19.635	.08	.3997	13209.98
37	4.453	19.83	15.574	.06	.3170	16654.70
38	3.965	15.72	12.347	.05	.2513	21006.60
39	3.531	12.47	9.7923	.04	.1993	26487.84
40	3.144	9.88	7.7635	.03	.1580	33410.05

*1 mile pure copper wire 1-16 in. diam. = 13.59 ohms at 15.5° C. or 59.9° F.

1 circular mil is .7854 square mil.

CHAPTER III

Current Generation in Dynamos — Dynamos — Brushes and Commutators.

Current Generation in Dynamos. If we take a coil of wire, Fig. 15, and rapidly thrust a magnet into it, we shall observe a certain deflection of the galvanometer needle shown with it. This deflection continues only while the magnet is in motion. After we have inserted the magnet and it has come to rest the galvanometer needle will return to its normal position. When we withdraw the magnet the deflection of the needle will be in the opposite direction. If the magnet is inserted or withdrawn with a very quick motion, the deflection will be considerable. If the magnet is very slowly inserted or withdrawn the deflection will hardly be noticeable. The

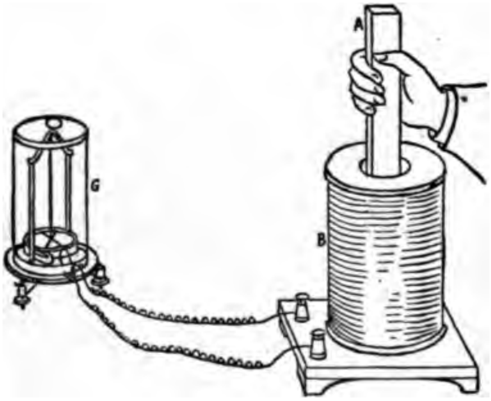


FIGURE 15.

same phenomena will occur if instead of moving the magnet, we hold it stationary and move the coil, or if both of them be moved towards or from each other. The deflection of the compass needle indicates that a current of electricity is passing along the wire, and the experiments above described show exactly how currents of electricity are produced in dynamos.

An electromotive force is induced by rapidly cutting "lines of force," that is, by moving either a magnet over a wire or a wire over or near a magnet. The current in turn is the result of this electromotive force acting in a closed circuit. A bar of iron becomes an electromagnet if we wind about it a few turns of wire and cause a current of electricity to flow along the wire, Fig. 16. The magnetism is conceived to consist of lines of force, which leave the bar at one end and enter it at the other, the direction of these lines depending upon the direction in which the current circulates about the bar of iron. The number of these lines of force depends upon the number of ampere turns in the iron bar and on the diameter, length and quality of the iron bar.

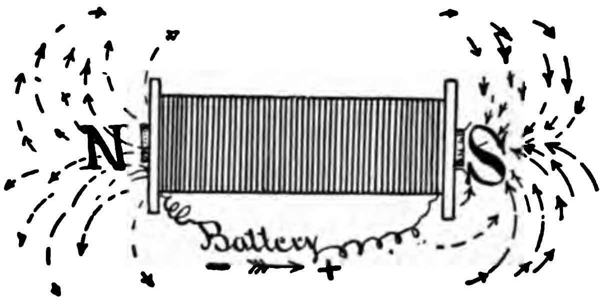


FIGURE 16.

Ampere turns is a term used to indicate the magnetizing force; it is the number of turns of wire on a magnet multiplied by the current in amperes flowing through these turns of wire.

Haskins, in *Electricity Made Simple*, explains this thus: "If, for instance, we have a current of one ampere flowing through a single turn of wire around a bar of soft iron and we have developed enough magnetism to lift a keeper or other piece of iron, weighing one ounce, then with one-half the amount of current and two coils around the bar, we would obtain the same result, and with three turns of wire we would require but one-third the current to develop the same lifting power in the bar or magnet."

The law of magnetic flow is very much the same as the law of current flow. If the iron bar is of low magnetic resistance, the flow will be quite great; if of high resistance, the flow will be small.

Lines of force can also be shunted just as a current of electricity can; that is, they will follow the path of lowest resistance just as a stream of water or a current of electricity will.

Now let us consider the elementary sketch of a dynamo, Fig. 17. The wire *a* represents the armature and we have also the iron bar and the coil of wire wound on it and, for the present, we may consider the battery B as the source of the current which produces the magnetism or lines of force in the iron bar. The battery current magnetizes the iron bar (which in dynamos is known as the field magnet) and produces the lines of force indicated by arrows.

These lines of force leave the field magnet of our dynamo at the north pole marked N, and pass through the air-gap and armature into the south pole marked S.

As we begin to move the wire or armature, it cuts through these lines of force and begins to generate an electromotive force, which in turn will cause the current to flow if the circuit is closed through a lamp or other device.

This current reverses in direction as the wire *a* passes from the influence of the south pole into that of the north pole and the brushes B′ and B″, which transmit the current to the outside wires, are so set that they change the connection of the wire *a* at the time that it passes from one pole to the other. By this means the current in the external circuit is kept constant in direction, although it alternates in the armature.

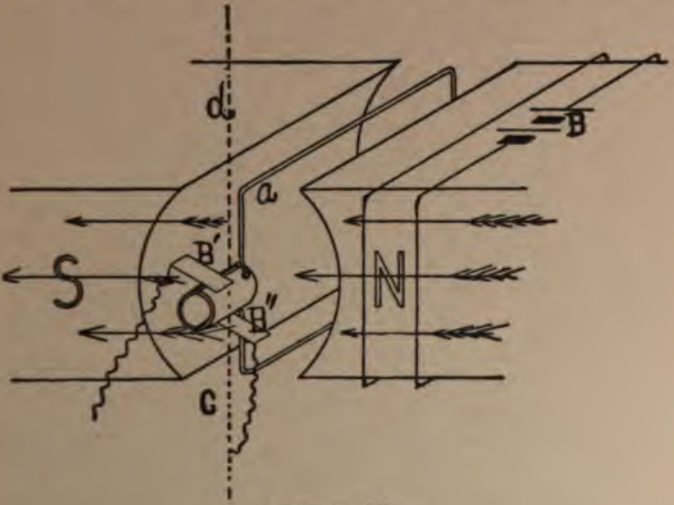


FIGURE 17.

The faster we turn our wire or armature, the greater will be the electromotive force generated. Instead of using only one wire, as in Fig. 17, we may take many turns before bringing the end out, and in so doing obtain the well known drum armature, or, by a slightly different method of winding, the gramme ring armature, Fig. 18. Here we have many wires cutting the lines of force at once and our electromotive force with the same number of revolutions of the armature is correspondingly increased, and the more turns of wire we arrange to cut those lines of force per second the greater will be our E. M. F. Instead of providing more wire or increasing the speed of our armature we can increase the magnetism, or number of lines of force, by sending more current through the fields, that is increasing the "ampere turns."

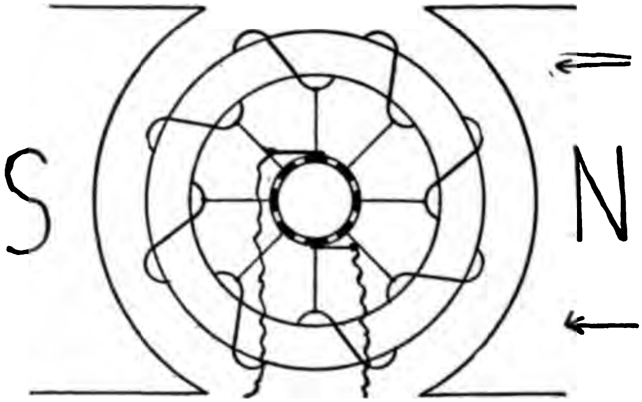


FIGURE 18.

If we wish to reverse the current flow we can do so by revolving the armature in the opposite direction, or by reversing the current through the fields.

Dynamos. Having so far considered the generation of currents in dynamos, we may now consider different types of dynamos and their uses. Fig. 19 shows a diagram of the wires and connections of a series dynamo. The principal use of this dynamo at present is in connection with series arc circuits. (See Fig. 7.) This dynamo is usually equipped with an automatic regulator (which will be explained later) to raise or lower the voltage as the number of lamps increases or decreases, the current remaining constant at about 10 amperes. By reference to the figure, we can trace the current as it flows from the + brush, in the direction of the arrows, around both field magnets and through the lamps, returning to the – brush on the dynamo. In our elementary sketch of a dynamo we used battery current to magnetize our fields; we need not consider

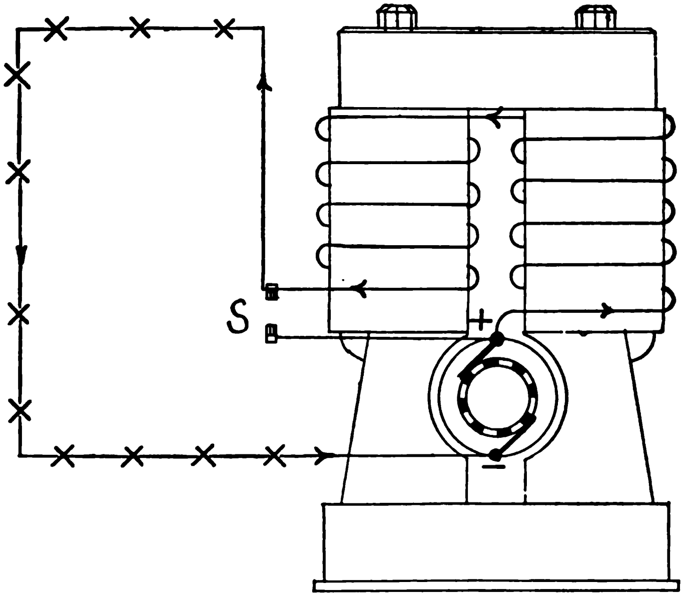


FIGURE 19.

that any more, for in practice all direct current dynamos produce their own magnetism by circulating some or all of their current through the field coils.

In the shunt wound dynamo, Fig. 20, the wire in the field winding is of such size and connected in such a manner as to have a resistance so high that only a portion of the main generated current of electricity passes around the field magnets. The quantity of current passing around these field magnets is also regulated by a resistance sometimes called a rheostat shown at R. The resistance to the flow of current through this box is adjusted by hand by the attendant and the flow of current through this rheostat and around the

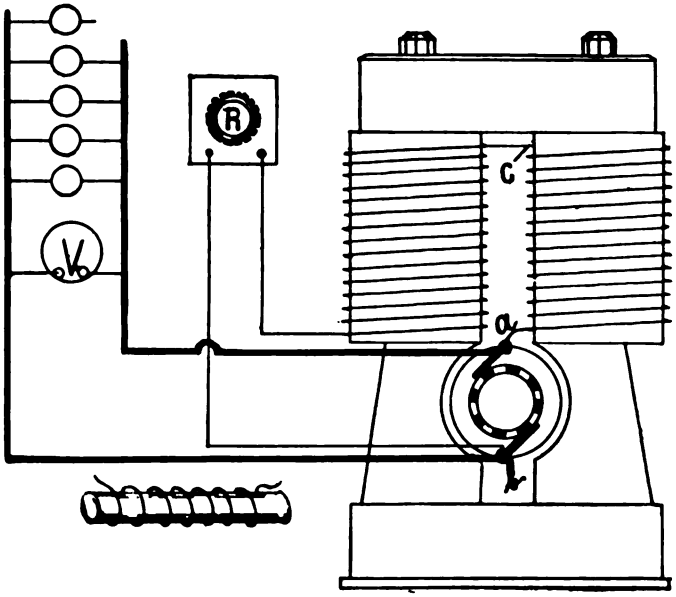


FIGURE 20.

field magnet is what determines the electromotive force of the dynamo.

This type of dynamo is used for electric lighting and for operating motors. The electromotive force of such a dynamo remains nearly constant, but the current varies with the number of lights or motors used. If it were connected to too many lights it would deliver too much current and become overheated and perhaps burn out. The current leaves at the + brush, passes through whatever lamps happen to be switched on and returns to the – brush.

Fig. 21 shows a diagram of a compound wound dynamo. This is really a combination of the series and shunt dynamos. If the current in a series dynamo is not kept constant the magnetism in the fields will vary as the current varies, and consequently its voltage will be very unsteady. This makes such a dynamo unfit for use with variable currents.

The voltage of a shunt dynamo is quite constant with variable loads, but still it leaves much room for improvement; not because of any variation in the induced electromotive force, but because of the losses occurring in the armature and wires conveying current. The loss of voltage in the armature and line equals the current multiplied by the resistance; consequently, as the current increases more and more volts are lost and the pressure goes down. If we would have the pressure remain at its normal value, we must find some way to increase the field magnetism as the current delivered by the dynamo increases, and this is the purpose of the compound winding. The compound winding carries the total current of the dynamo around the fields, but only a few times, just often enough so that the increase in magnetism resulting from this current may make up for the loss in the armature or line. Dynamos may be compounded for any per cent. of loss desired.

The foregoing descriptions are those of direct current dynamos, and they are called direct or continuous

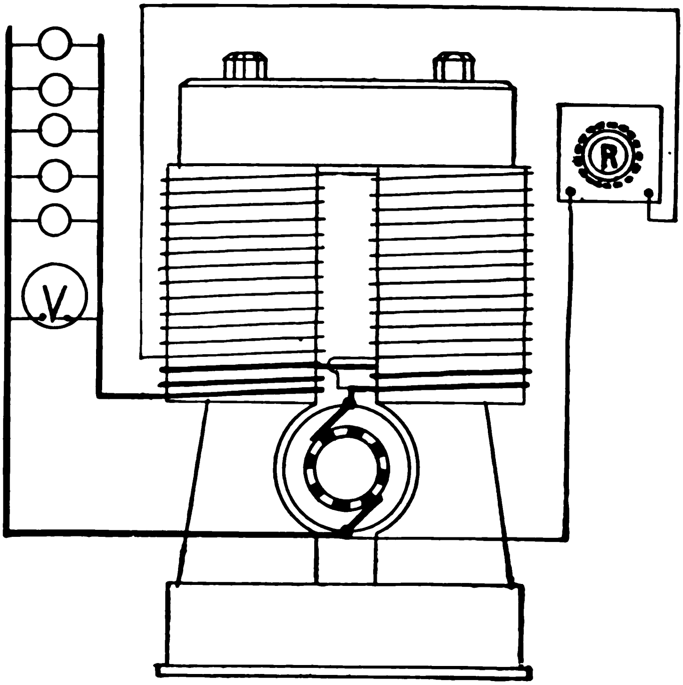


FIGURE 21.

current dynamos because the current flow continues in one direction out of the positive or + side of the dynamo, to the external circuit, and back again to the negative or – side of the dynamo. The current as it is generated in the coils of the armature which revolves between the field or pole pieces, is alternating; that is to say, if the armature wires were connected to collector rings the current in the outside wires would be reversed every time the position of the wire in the armature were changed from the influence of one pole piece to that of the other. If the coils constituting the armature are connected to a device called the commutator, they will be commutated or rectified.

Such a commutator is formed of alternate sections of conducting and non-conducting material, running parallel with the shaft with which it turns. It is placed on the shaft of the armature so that it rotates with it, as shown in Fig. 22. The brushes press upon its surface and collect the current from the bars. (See Fig. 31.) The function of the commutator is to change the connections of the armature coils from the + or positive to the negative or – side of the circuit at the time at which the coil connected to the bar under the brush passes from the influence of one pole piece into that of the other. This is the time at which the current in the coil reverses in direction, and is called the neutral point. If we consider, for the sake of simplicity, an armature having only one turn of wire on it, as Fig. 17, there will be a time while the coil is in the

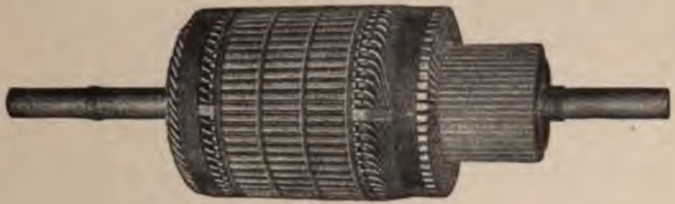


FIGURE 22.

position indicated by dotted lines at *c* and *d* when no current is being generated. The brushes on any dynamo should always be set at this point, for this is the point of least sparking. In actual practice all commutators have quite a number of bars and it is impossible to avoid, in passing under the brushes, that at least two of them are in contact with a brush at the same time. If a brush did leave one bar before it touches another, the current would be entirely broken for that length of time and much sparking would result. The nature of all armature windings is such that while the brush is in contact with the commutator bars it short circuits that coil between them. This is the main reason why the brushes must be kept at a point at which the coil which is short circuited generates no current.

Although the electromotive force generated in one coil of a dynamo is very small, the resistance of the "short circuit" formed by the dynamo brush is also very small and therefore the current may be quite large. This current is the main cause of sparking in dynamos. The number of bars constituting a commutator depends upon the winding of the armature, and the number of coils grouped thereon. By increasing the number of coils and commutator sections the tendency to spark at the brushes is decreased, and the fluctuations of the current are also decreased. However, there are many reasons against making the number of bars on a commutator very great. Increasing the number of bars in a commutator increases the cost of manufacture, and in smaller dynamos if the number of bars be increased beyond a certain extent, each bar becomes so thin that a brush of the proper thickness to collect the current from the commutator would lap over too many bars of the commutator at one time. Each commutator bar should be of the size that will present sufficient metal for the carrying capacity of the current generated in the coil to which it is connected. Different builders of dynamos have different ideas as to the number of amperes that may be carried per square inch in a commutator bar, but where a commutator is made of 95 per cent. copper it is usual to allow for each 100 amperes a commutator bar surface of 1½ sq. in.

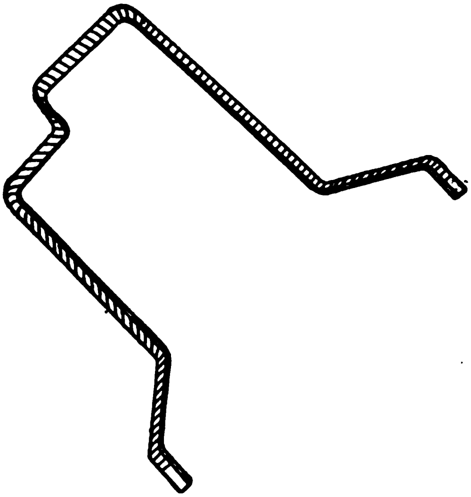


FIGURE 23.

The method of electrical connection between the commutator bar and the coil of the armature varies in different designs. Some builders solder the terminals of the coils to the commutator bars; others bolt the terminals of the coils to the bars; and some makers use hard drawn copper and "form" the armature coil in such a manner that both ends of the coil become commutator bars, making the coil continuous from one end of the commutator bar to the end of the diametrically opposite commutator bar.

In Fig. 23 we show a so-called "formed" armature coil, after it has been prepared by properly insulating it and bending it into shape ready to be applied to the laminated armature body.

In Fig. 24 is shown a "formed" coil armature with the winding almost finished. The commutator is yet to be placed on the shaft and the coil terminals connected to the commutator bars.

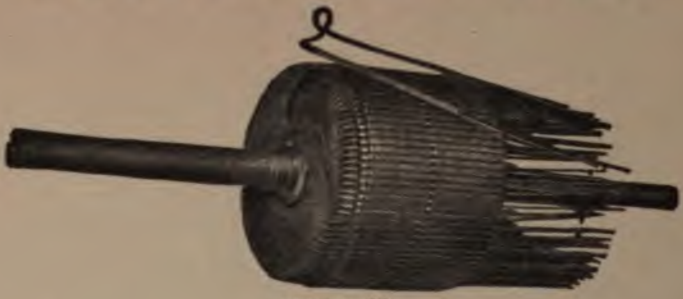


FIGURE 24.

In Fig. 25 we have an armature shaft with the laminated armature body keyed on to the shaft ready to be wound.

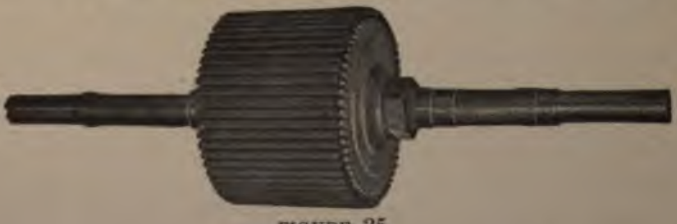


FIGURE 25.

The body on which the armature coils are to be wound is made up of sheet iron punchings and placed on the armature shaft in the same manner that you would put ordinary iron washers on a lead pencil. These punchings or discs are insulated from one another by having previously been painted with a coat of shellac; for there is the same tendency to produce current in the iron part of the armature, due to the cutting of the magnetic lines, as there is in the copper wire which is wound on its surface. If the iron core were solid, there would be a very large current circulating in the same direction as that which flows through the wires. Such a current would be entirely useless and would heat the armature; to prevent this the armature is built up of thin sheet iron discs.

Brushes and Commutators. Figs. 26 to 30 show different arrangements of modern brushes and brush-holders. These are used to take the current from the commutator and deliver it to the outside wires in the case of a dynamo, and for the opposite in the case of a motor.

There are many different designs and constructions of brushes and brush-holders, and these designs are brought about by the various ideas of different builders in their attempt to produce various advantageous results, but the electrical connections and underlying principles remain the same whether a copper or a carbon brush be used.

In any construction of brush holding device, if great care is not exercised in keeping it thoroughly clean, trouble is sure to be the result, and trouble of this nature increases so rapidly that unless the attendant immediately sets about to right it, a burned out armature is almost sure to be the consequence sooner or later. In alternating current dynamos, where brushes rest on collector rings instead of commutators, it is much easier to keep out of trouble, because the brushes in this case merely collect the current from the rings and do not commutate or rectify it.

The brushes and commutator of a dynamo or motor are probably the most important parts with which the engineer has to deal. Great care should be taken that the brushes set squarely on the commutator and that the surface of the brushes and commutator are as smooth as possible. It is a good plan, and in some

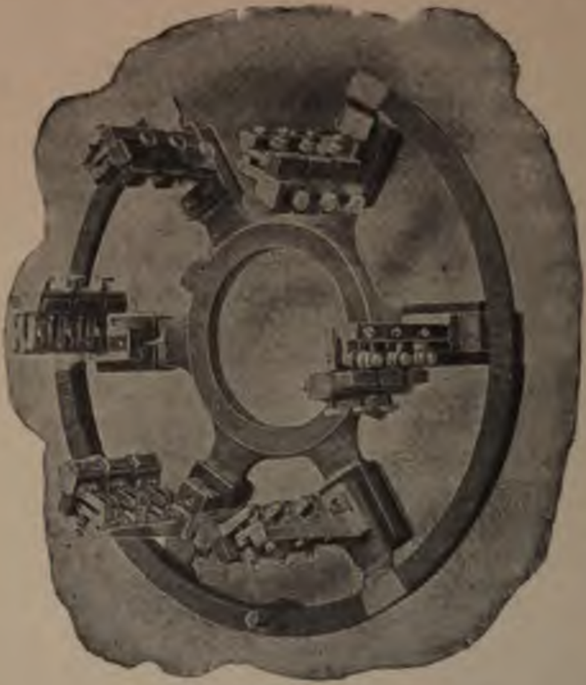


FIGURE 26.

cases the brush-holders are so made, that the brushes set in a staggering position, that is to say, in a position so that all the brushes will not wear in the same place over the circumference of the commutator and

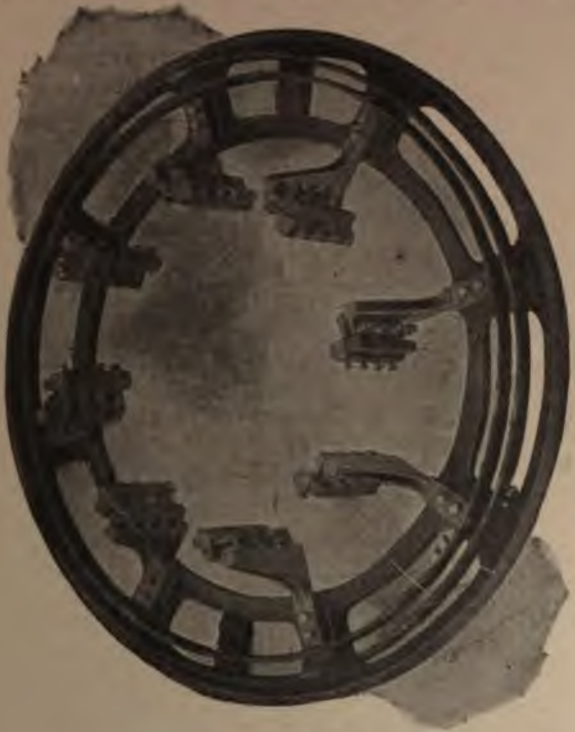


FIGURE 27.

cause uneven wear across the length of the commutator bars. In most machines the armature bearing is left so that there is more or less side motion, which, when the armature is running, causes a constant changing of the position of the brushes and commutator.

Whatever style of brush is used, the commutator should be kept clean and allowed to polish or glaze itself while running. No oil is necessary unless the brushes cut, and then only at the point of cutting. A cloth (not cotton waste) slightly greased with vaseline and applied to the surface of the commutator while running is best for the purpose of preventing the commutator from cutting. Should the commutator become rough, it should be smoothed with sandpaper, never using emery cloth, because emery cloth is conductor of electricity, and the particles of emery are liable to lodge themselves between the commutator bars in the mica and short circuit the two bars, thereby

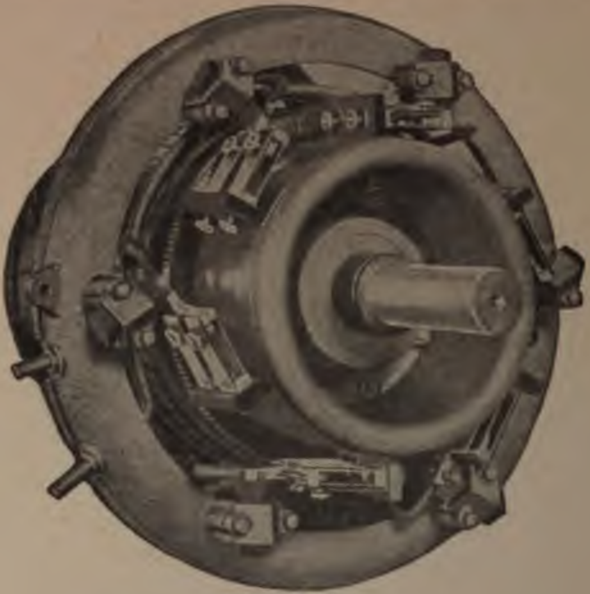


FIGURE 28.

burning a small hole wherever such a particle of emery has lodged itself. The emery will also work into the brushes and copper bars and wear them down; it being almost impossible to remove all the emery.

In the end-on carbon brushes, Fig. 30, the contact surface of the brushes should be occasionally cleaned by taking a strip of sandpaper, with the smooth side of the paper to the commutator, and the sanded side toward the contact surface of the brush, and then by leaving the tension of the brush down on the sandpaper, it is an easy matter to move the sandpaper to and fro and throughly clean off the glazed and dirty surface from the carbon, leaving it with a concave that will exactly fit the commutator.

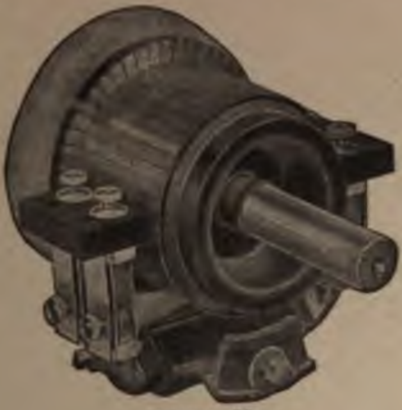


FIGURE 29.

The advantages of carbon brushes are many. Among the cardinal points are: The armature may run in either direction without it being necessary to alter the brushes; the carbon can be manufactured with a quantity of graphite in its construction, thereby lowering the mechanical friction of the brushes on the commutator; they do not cut a commutator so much by sparking; the commutator has a longer life, the wear being more evenly distributed.

Carbon brushes, due to their rather high resistance, will often heat up considerably, but, although this heat is objectionable, their resistance tends to cut down the sparking. The brushes are sometimes coated with copper to reduce their resistance. Often a carbon brush will be found which is very hard. As a rule such a brush should be thrown away, as it will heat abnormally and at the same time wear the commutator.

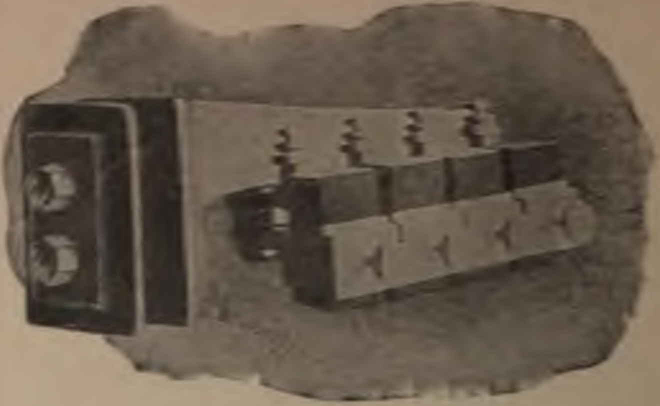


FIGURE 30.

In Fig. 31 we have one of the various so-called old styles of leaf brush-holders. The end-on brushes are more generally used in modern practice, because their contact surface area is not increased or decreased by wear. Consequently the brushes always remain in a diametrically opposite position. With the old style brush-holding device, where the brushes rest on the commutator at a tangent, great care should be exercised not to allow the brushes to wear in a position so that their points will be out of diametrical opposition.

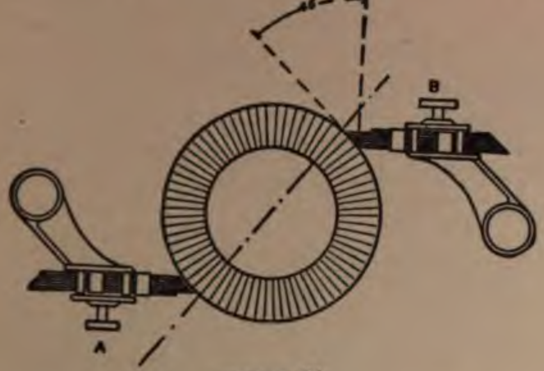


FIGURE 31.

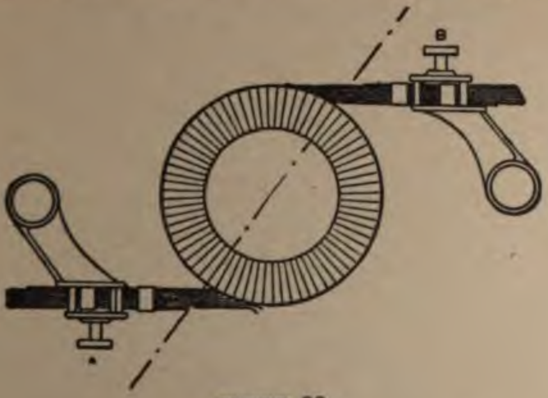


FIGURE 32.

In Fig. 31 we show the correct way that this type of brush should be set.

In Figs. 32 and 33 we show the incorrect way.

By remembering that each one of the commutator bars is the end of a coil, and then just mentally tracing the current through the coils from one brush to the other, we can readily understand what the results are when the brushes are neglected and left in a relative position, as shown in these figures.

Sparking is the usual result of brushes allowed to wear to such an extent. Overloading of a dynamo or motor will also cause serious sparking, and no amount of care can prevent damage to armature, commutator or brushes, if a machine is permitted to be overloaded

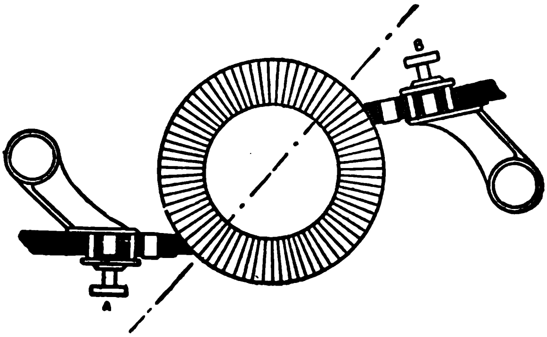


FIGURE 33.

Sometimes the commutator will contain one or more bars which, as the commutator gets old and wears down, will wear away either too fast or too slow, due to the metal being harder or softer than the rest of the bars forming the commutator. This causes a roughness of the commutator and results in the flashing of the brushes and heating of both the commutator and brushes. About the only satisfactory method of remedying this evil is to take out the armature and have the commutator turned down in a lathe.

A short-circuited coil in the armature, or a broken armature connection, will also cause considerable sparking. Either of these conditions can be located by means of a Wheatsone bridge or by what is known as the fall of potential method. To make a test with this latter method, connect in series with the armature to be tested some resistance capable of carrying the necessary current, also an ammeter. Some apparatus for varying the current strength, such as a water rheostat or lamp rack, must be connected in the circuit, a diagram of which is shown in Fig. 34.

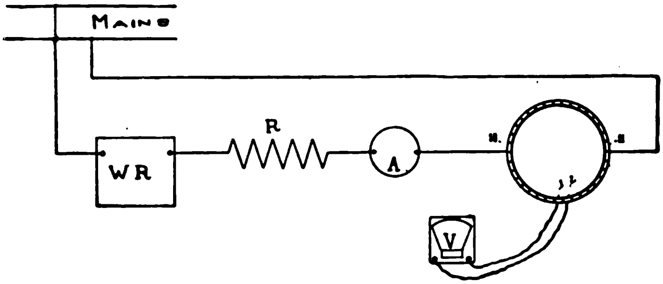


FIGURE 34.

In the diagram, WR is the water rheostat or lamp rack, R the known resistance, A the ammeter and M the armature to be tested. By means of the water rheostat regulate the current passing over the apparatus until it is of such strength that a deflection can be obtained on a voltmeter when it is connected to two adjacent bars on the commutator. Suppose the armature coil between bar 1 and 2 on the commutator were broken. The voltmeter connected across these two bars would give the same reading as when connected

[illegible]

[illegible] types. It is [illegible] every change of [illegible] armature makes a [illegible] of the armature opposes that of the fields. In Fig. 35 the armature is working with a very light load and the lines of force of the field magnets are only slightly opposed by those of the armature. In Fig. 36 we assume a heavy load on the dynamo and consequently the magnetism of the armature opposes that of the fields. This changes the location of the neutral point (when the coils under the brush generate no current) and it becomes necessary to shift the brushes accordingly, or great sparking would result. The amount of shifting necessary with changes of load varies in different dynamos. If the field is

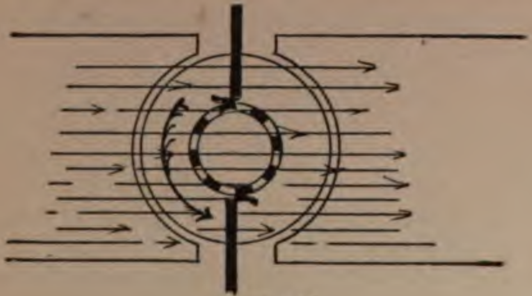


FIGURE 35.

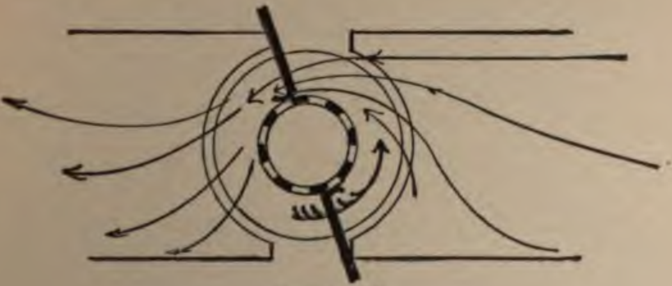


FIGURE 36.

very strong compared to the armature, it will be but little. If the armature (as in some arc dynamos) is very strong compared to the field, it will be considerable.

In dynamos, with increasing load, the brushes should be shifted in the direction of rotation and in the opposite direction when the load decreases.

Never allow a dynamo or motor to stand in a damp place uncovered. Moisture is apt to soak into the windings and cause a short circuit or ground when started. Great care should also be used should it ever be found necessary to use water on a heated bearing. If the water is allowed to reach the armature or commutator, it is bound to cause trouble. Water should only be used in case of emergency, and then sparingly.

CHAPTER IV

OPERATION OF DYNAMOS

Constant Potential Dynamos. In order to thoroughly explain the operation of dynamos, let us assume that we have the task of starting a new shunt dynamo, one that has never generated any current. Our first step is to open the main switch and turn the rheostat or field resistance box so that all the resistance is in circuit. A rheostat consists of a number of resistances, Fig. 37, so arranged that they can be cut in or out of the circuit without opening the circuit. By reference to the figure it will be seen that the current enters at the handle and from there passes to the contact point upon which the

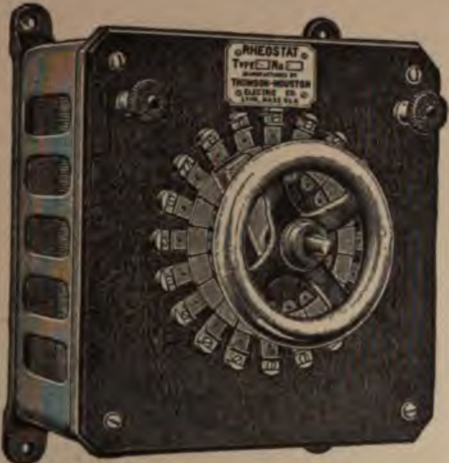


FIGURE 37.

handle happens to rest. If the handle is at 1 the current must pass through all the wire in the box; if it is at 2 it simply passes through the handle and out.

Rheostats for the shunt circuit of a dynamo should have sufficient resistance, so that when it is all inserted the voltage of the dynamo will slowly sink to zero. This method of stopping the action of a dynamo is perfectly safe and should be followed wherever possible.

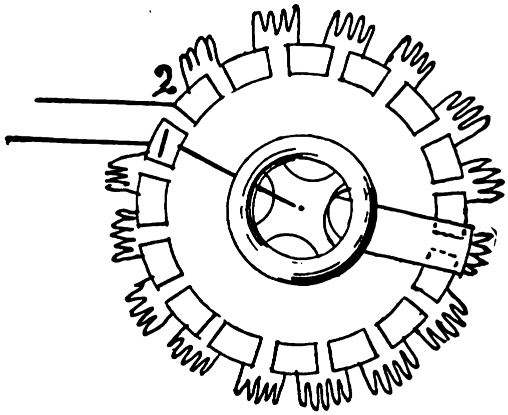


FIGURE 37.

We are now running our dynamo with all resistance in the shunt circuit. This is simply as an extra precaution because we know nothing about this particular dynamo. When it is known that the dynamo is in good order, the engineer or attendant usually cuts out all the resistance, and as the generator builds up or, in other words, generates current, he proceeds, by the aid of the resistance box, to cut down or diminish the flow of electricity around the field magnets of the dynamo, and thereby diminish the magnetic density of the field magnets and the electromotive force of the dynamo.

We must now gradually turn our rheostat so as to cut out resistance and watch the voltmeter, which is connected as shown at V in Fig. 20, and receives current whenever the dynamo is operating. Suppose that the voltmeter indicates nothing, and we find that the dynamo will not generate. On examination of all the connections we find everything correct, and we now discover that the dynamo field magnets do not contain what is termed "residual magnetism" sufficient to start the process of generating current.

Before an armature can generate current it must cut lines of force, that is, it must revolve in a magnetic field. If the dynamo has been generating current it is likely that the iron cores of the field magnets will retain sufficient magnetism to start the generation of current again. This magnetism which remains in the iron is known as residual magnetism. It will make itself manifest by attracting the needle of a compass, or if strong, a screw driver or a pair of pliers. If we find no magnetism in the iron core of the field magnets, we may take the ends of the shunt winding on the field magnets and pass current over them from a battery. This current will produce sufficient magnetism to cause the generator to build up; in other words, if we disconnect these batteries, and connect the wires back again from where we got them, we will find that we can generate current with the machine.

When the machine begins to generate, we watch the voltmeter and cut resistance in or out of the circuit according whether we need to lower or raise the voltage. If we have only one dynamo we may close the main switch before we begin generating or after we have attained full voltage.

Again referring to the pole pieces on the dynamo, it is possible that there is a sufficient quantity of residual magnetism in the pole pieces, and that the polarity of both field magnets, between which the armature is revolving, is the same. This would also cause the dynamo to fail in generating current. If sending battery current through the coils does not make one field a north pole and the other a south pole, one of the fields must be connected wrong, and we must make some changes in the connection.

Referring to Fig. 20, a and b are the terminals of the shunt winding on the fields. If the winding of the fields is correctly put on it will be as in the little sketch at lower corner; that is, if both field magnets were taken out of their places and put together, the winding should run as one continuous spool. But if the winding on one field is wrong, we need simply change its connection, as, for instance, transferring c to a and a to c.

In order that a dynamo may excite itself, it is necessary that the current produced by the residual magnetism shall flow in such a direction as to strengthen this residual magnetism. If the current produced by the residual magnetism flows through the field coils in the opposite direction this will tend to weaken the residual magnetism and consequently to reduce the current which flows.

For this reason if the first attempt to start a dynamo with battery current fails, the battery should be applied with the opposite poles so that the magnetism it produces in the fields will be in the opposite direction.

The magnetism, the fields, and all parts of the dynamo may be in perfect working order and yet a short circuit in any part of the wiring will prevent the dynamo from building up This short circuit will furnish a path of such low resistance that all current will flow through it and none can flow through the fields to induce magnetism. Often dynamos fail to generate because of broken wires in the field coils, poor contacts at brushes, or loose connections. Sometimes also part of the wiring may be grounded on the metal parts of the dynamo frame. A faulty position of the brushes may also be a cause for the machine not generating. In some machines the proper position for the brushes is opposite the space between the pole pieces, while in other machines their proper position is about opposite the middle of the pole piece. If the exact position is not known, a movement of the brushes will sometimes cause the generator to build up.

If there are several dynamos to be started great care must be taken to see that the second machine is operating at full voltage before the switch is closed connecting it to the switch board. The voltage should be exactly the same as that of the first machine and the rheostat worked to keep it so. If it is less, it is possible that the first machine will run the second as a motor; if it is more, the second machine may run the first as motor, the machine having the higher voltage will always supply the most current.

It is also necessary before throwing in the second machine (connecting it to the switch board) to see that its polarity is the same as that of the machine with which it is to run. By reference to Fig. 38 it will be seen that the + poles of both machines connect to the same bar, and if one of these machines is running and we wish to connect the other with it, we must first be sure that the wire of the second machine which leads to the top bus-bar is of the same polarity. That is, if the top bus-bar is positive, or sends out current, the wire of all dynamos connected to it must also be positive. The simplest way to find the positive pole of a dynamo is with a cup of water. Take two small wires and connect one to each of the main wires of the dynamo and then insert the bare ends of both wires into the water, small bubbles will soon be seen to rise in the water from one of the wires. That wire which gives off the bubbles is the negative wire. Take care that in making this test you do not get the ends of the small wires together or against the metal of the cup or you will form a short circuit. The polarity of both dynamos must be tested and wires of same polarity connected to the same bus-bar.

Where several machines are to be operated in parallel, compound dynamos are generally used, because it is troublesome to keep two shunt machines working in harmony.

The starting of a compound wound dynamo is the same as that of a plain shunt dynamo, but in connecting a compound wound dynamo to its circuit it is necessary to be sure that the shunt coils and series coils tend to drive the lines of force around the magnetic circuit in the same direction. If the series coil is connected up in the opposite direction to the shunt coil the dynamo will build up all right and will work satisfactorily on very light loads. When, however, the load becomes even, five or ten per cent. of full load, the voltage drops off very rapidly and it is impossible to get full voltage with even half the load on. This is because the ampere turns due to the series coils decrease the total ampere turns acting on the magnetic circuit instead of increasing them as the load comes on. This lowers the magnetic flux and of course lowers the resulting voltage. In such a case it will be necessary to reverse either the field or series coils.

Fig. 38 and the following description of compound dynamos and their connections is taken from *Wiring Diagrams and Descriptions*, by Horstmann and Tousley, published by Frederick J. Drake & Co., Chicago.

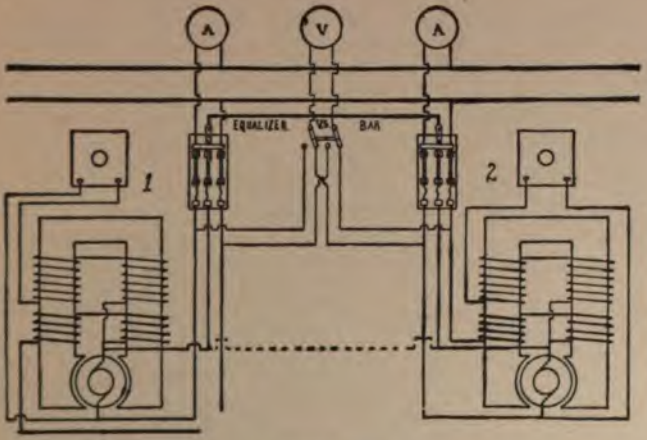


FIGURE 38.

Fig. 38 shows connections for two compound wound dynamos run in parallel. When two or more compound wound dynamos are to be run together, the series fields of all the machines are connected together in parallel by means of wire leads or bus-bars which connect together the brushes from which the series fields are taken. This is known as the equalizer, and is shown by the line running to the middle pole of the dynamo switch. By tracing out the series circuits it [illegible] the upper brush of [illegible] fields and the other by [illegible] through the fields of the [illegible] machines are gener- [illegible] difference of potential between [illegible] Should from any [illegible] current [illegible] begin to flow through [illegible] at the same [illegible] again equal. The [illegible] much cur- [illegible] It may also be the [illegible] this will save all [illegible] The [illegible] as shown. If they [illegible] under the [illegible] and would indicate [illegible] The equalizer [illegible] In some cases the [illegible] switch is [illegible] The [illegible] variable [illegible] compound ma- [illegible] speed, there- [illegible] shunt and series coils [illegible]

[illegible]

[illegible]

[illegible] good contact.

[illegible] from scraps [illegible]

5. Keep all the insulations free from metal dust or gritty substances.

6. Do not allow the insulation of the circuit to become impaired in any way.

7. Keep all bearings of the machine well oiled.

8. Keep the brushes properly set and see to it that they do not cut or scratch the commutator.

9. If the brushes spark, locate the trouble and rectify it at once.

10. The durability of the commutator and brushes depends on the care exercised by the person in charge of the dynamos.

11. At intervals the dynamos must be disconnected from the circuit and thoroughly tested for leakage and grounds.

12. In stations running less than twenty-four hours per day, the circuit should be thoroughly tested and grounds removed (if any are found) before current is turned on.

13. Before throwing dynamos in circuit with others running in multiple, be sure the pressure is the same as that of the circuit; then close the switch.

14. Be sure each dynamo in circuit is so regulated as to have its full share of load, and keep it so by use of resistance box.

15. Keep belting in good order; when several machines are operating in parallel and a belt runs off from one, the others will run this machine as a motor.

16. In the same way if you shut down an engine driving a generator, the other generators will run the generator and the engine.

Constant Potential Switchboard. In Fig. 39 we show the usual type of switchboard employed to connect, or switch various dynamos and to feed various circuits from. These types, sizes and arrangements of switchboards vary and depend entirely on the type and size of the plant, the number of dynamos used and the number of circuits to be controlled. The switchboard in this cut has three dynamo panels and one load panel. At the left of the board and near the top is the voltmeter, while on the three left panels are the dynamo main switches and their respective amperemeters. On the lower part of these three machine panels will be noticed the protruding hand wheels of the field resistance boxes, which are hidden back of the board. The meter at the top of the right hand panel is the load amperemeter and registers the total number of amperes that are being supplied to the circuits whose several switches are just below the meter.

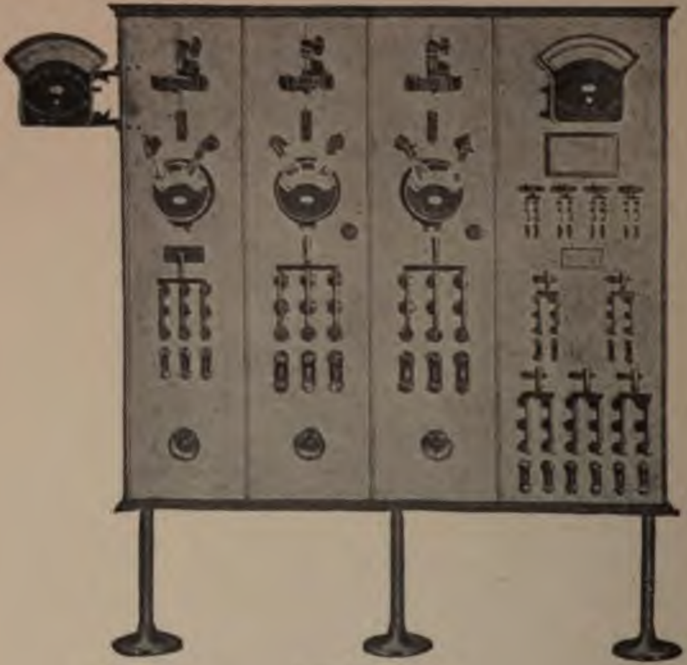


FIGURE 39.

Fig. 40 shows diagrammatically the reverse side of a similar switchboard. Below all of the switches there are installed fuses in each wire. The object of these fuses is to protect the wires and also the dynamos. These fuses consist of an alloy which melts at a comparatively low temperature. If, for instance, a short circuit occurs in any line, the current will suddenly become very great and will generate considerable heat. This heat will cause the fuse to melt and open the circuit. If the fuse did not melt the current would continue and overheat the wires, causing considerable damage and perhaps fires. The fuses should always be chosen of such a size that they will melt before the current rises enough to do any damage.

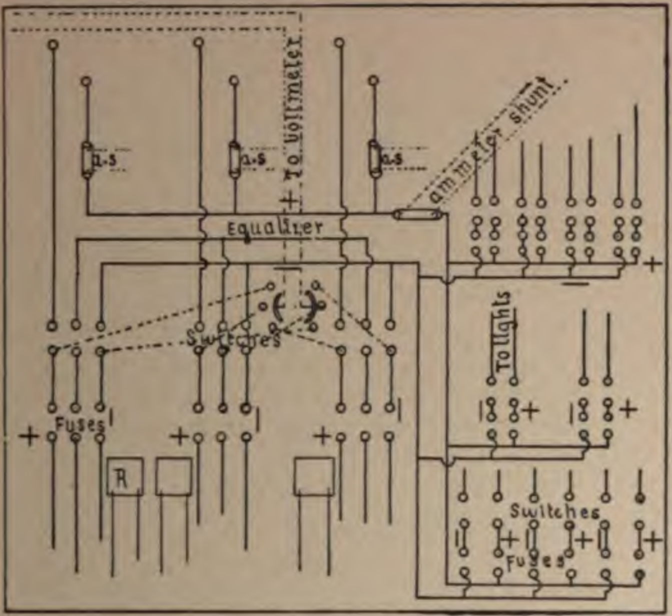


FIGURE 40.

Operation of Constant Current Dynamos. Constant current dynamos differ from constant potential dynamos mainly in the higher voltage for which they are usually constructed. Such machines are always more or less dangerous to life, and great care must be taken not to touch any of the current-carrying parts with bare hands.

When such parts must be handled rubber gloves are very convenient and useful if kept dry. High voltage machines should always be surrounded by insulating platforms of dry wood, or rubber mats, so arranged that one must stand on them in order to touch any part of the machine. By reference to Fig. 19 it will be seen that the constant current dynamo is not equipped either with a voltmeter or a field rheostat; but an amperemeter should always be used. The troubles encountered with these dynamos are much the same as those of constant potential dynamos. Most of them are referred to in the following descriptions and instructions for different systems and to avoid repetition need not be mentioned here.

The type of dynamo generally used with constant currents is shown in Fig. 19 and is series wound; that is, the same current that passes through the lights also passes through the fields and excites them. The fields of this dynamo are connected with a short circuiting switch, S, which is generally used when the machine is to be shut down. When this switch is closed it forms a path of much lower resistance than do the fields of the dynamo and all current passing through it and the dynamo loses its magnetism and stops generating. A constant potential dynamo will not begin generating if there is a short circuit anywhere in the wiring connected with it, but with the constant current dynamo it is often necessary to provide a short circuit in order to start it. If there is very much resistance in the line or if it is entirely open the dynamo will fail to generate.

In order to start generation a small wire may be attached to one of the terminals of the dynamo and the other end brought in contact with the other terminal for a fraction of a second or the shortest possible instant. If the circuit happens to be arranged somewhat as shown in the figure, the plug may be inserted so that the dynamo is started through only one lamp. When this lamp is burning properly the plugs may be suddenly withdrawn and the current will now force itself through the other lamps. This process is known as "jumping in" and should be used only in an emergency, as much damage may be caused, especially if a dynamo is already running a large number of lamps and is then "jumped into" a bad circuit. This is also often done, but is just as dangerous as it would be to attempt to start a heavy steam engine by opening up the throttle valve with a quick jerk.

Constant current dynamos are always equipped with automatic regulators and before the dynamo is started special attention must be given the regulator to see that it is in proper working order.

Often it may be desirable and even necessary to run two dynamos in series, as, for instance, if a circuit has been extended beyond the capacity of one machine. In such a case the regulator of one machine is cut out and that machine set to operate at about its highest electromotive force, and the variations are taken care of by the other dynamo.

The Brush System. The brush arc dynamo is quite distinct from other constant current dynamos in general use. We shall therefore give the following description of it taken from literature furnished by the General Electric Company.

The brush arc generator is of the open coil type, the fundamental principle of which is illustrated in Fig. 41. Two pairs of coils placed at right angles on an iron core, are rotated in a magnetic field. The horizontal coils represented in the diagram are producing their maximum electromotive force, while the pair of coils at right angles to them is generating practically no electromotive force. The brushes are placed on the segments of the four-part commutator, so as to collect only the current generated by the two horizontal coils. The other coils are open circuited or completely cut out of the circuit.

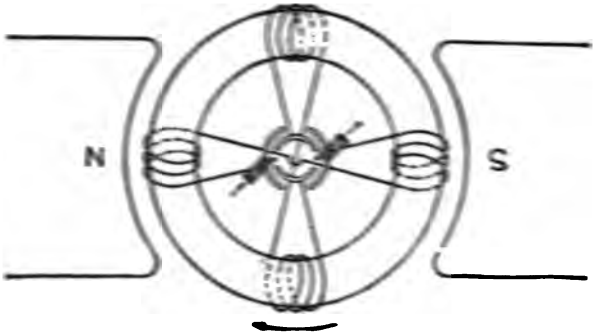


FIGURE 41.

Such a machine will generate current, continuous in direction, but fluctuating considerably in amount. These fluctuations will be diminished by the addition of more coils to the armature.

Fig. 42 shows the connections of an eight-coil brush arc generator. Each bobbin is connected in series with the one diametrically opposite. The connection is not shown on the diagram. It will be noticed that of those coils connected to the outer ring on which the brushes A and A' bear, only 3, 3' are in circuit, 1, 1' being entirely cut out; while on the inside ring all coils 2, 2^1 and 4, 4^1 are in circuit, the two pairs being parallel; 4, 4^1 are coming into the field of best action; in other words, they are approaching that part of the field in which there is most rapid change of magnetic flux, while 2, 2^1 are approaching that part in which the flux is uniform. In 4, 4^1 there is an increasing electromotive force being generated, and the current is rising; while in 2, 2^1, the electromotive force is decreasing and the current falling. Unless 2, 2^1 were cut out of the circuit, a point would soon be reached where the electromotive force in 2, 2^1 would be zero, and consequently 4, 4^1 would be short circuited through 2, 2^1. Just before this occurs, however, 2, 2^1 have passed from under the brush and the small current still flowing

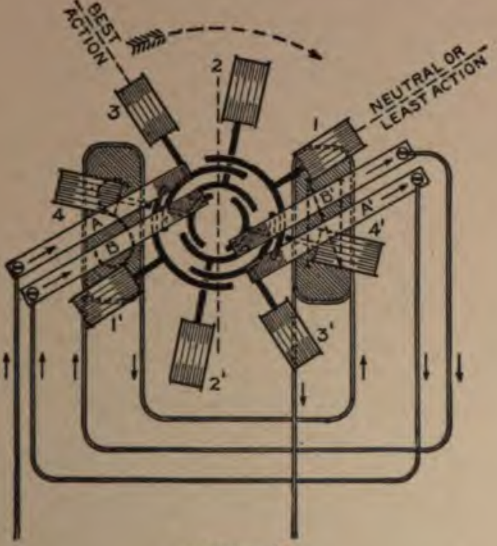


FIGURE 42.

draws out the spark one sees on the commutator of all open coil machines.

Setting the Brushes. A pressure brush should always be used over the under brush in the same holder, as it improves the running of the commutator and secures better contact on the segment. The combination is referred to as the "brush." The brushes should be set about 5⅛ in. from the front side of the brass brush-holder.

In setting the brushes, commence with the inner pair and set one brush about 5⅛ in. from the holder to tip of the brush, then rotate the rocker or armature until the tip of the brush is exactly in line with the end of a copper segment, as shown in Fig. 43. The other brush should be set on the corresponding segment 90° removed (the same relative position on the next forward segment); but if the length of the brush from the holder is less than 5⅛ in., move both brushes forward until the length of the shorter brush from the holder is 5⅛ in. Now set the two extreme outer brushes in the same manner, clamping firmly in position, and by using a straight edge or steel rule, all the brushes can be set in exactly the same line and firmly secured. The spark on one of the six brushes may be a trifle

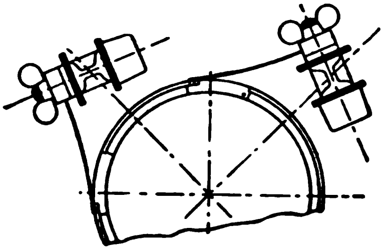


FIGURE 43.

longer than on the others. In this case, move the brush forward a trifle so as to make the sparks on the six brushes about the same length. Equality in the spark lengths is not essential, but it gives at a glance an indication of the running condition of the machine.

Brushes should not bear on the commutator less than ⅛ in. from the point of the brush, or, as illustrated in Fig. 44 (a), they will tend to drop into the commutator slots and pound the copper tip of the wood block, causing the fingers of the brushes to break off. If, on the other hand, the bearing is too far from the end, or the brushes are set too long, as in Fig. 44 (b), the point of the brush will not be in contact with the segment, thereby prolonging the break, and allowing the spark to follow the tip with consequent burning of the segments and brushes.

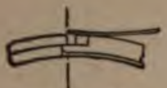


FIGURE 44A.

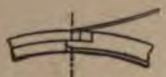


FIGURE 44B.

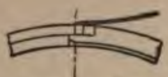


FIGURE 44C.

Fig. 44 (c) shows correct seating with the tip of the brush nearly tangential and stiff on the segment as it leaves.

Care of Commutator. If the commutator needs lubrication, oil it very sparingly. Once or twice during a run is ample. If the oil has a tendency to blacken the commutator instead of making it bright, wipe the commutator with a dry cloth. Too much oil causes flashing.

The machine, of course, generates high potential, and the cloth, or whatever is used to oil the commutator, should therefore be placed on a stick so that the hand is not placed in any way between the brushes.

A rubber mat should be provided for the attendant to stand on when working around the commutator or brushes.

One hand only should be used, and great care exercised not to touch two brush clamps or brushes at the same time; never with switches closed.

As soon as current is shut off from the machine the commutator should be cleaned. A piece of very fine sandpaper held against the commutator under a strip of wood for about a minute before the machine is stopped, will scour the commutator sufficiently. The brushes need not be removed. An effort should be made to have the machine cleaned immediately after it is shut down. Five minutes at that time will give better results than half an hour when the machine is cold. Never use a file, emery cloth or crocus, on the commutator. New blocks will sometimes cause flashing, due to the presence of sap in the wood. The machine should be run for a few hours with a slightly longer spark, say ½ in., and the commutator then thoroughly cleaned with fine sandpaper.

All constant current arc machines require an automatic regulator to increase the voltage as more lamps are cut into the circuit and decrease it as lamps are cut out.

We will give only one of the several forms of regulators used with this system.

The form I regulator is placed on the frame of the machine beneath the commutator, and a constant motion is imparted to its main shaft through a small belt running around the armature shaft. (See Fig. 46.) By means of magnetic clutches and bevel gears, a pinion shaft is rotated, which moves the rack and the rocker arm and so shifts the brushes on the commutator to maintain a spark of about 3/8 in. on short circuit and 1/8 in. at full load; at the same time the rheostat arm is moved over the contacts to cut resistance in or out of the shunt around the field circuit.

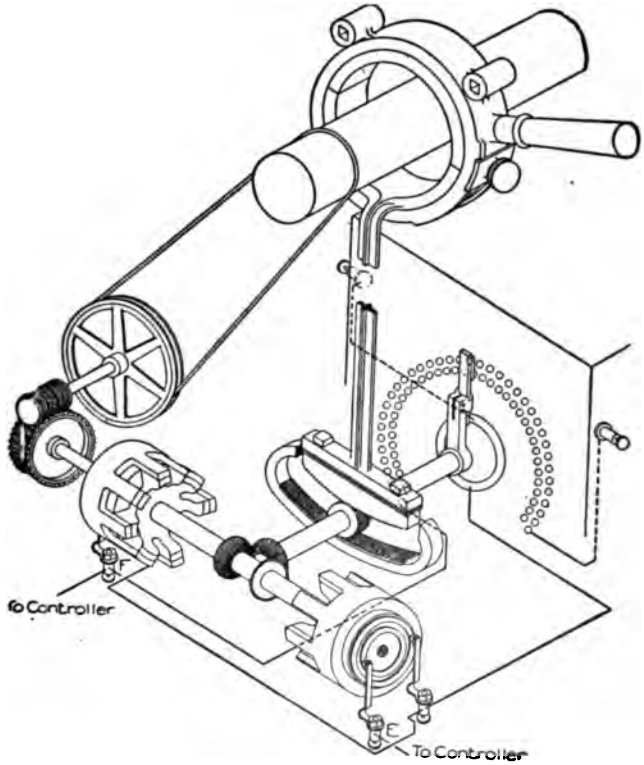


FIGURE 46.

The current for the magnetic clutches is regulated by the controller.

The controller consists principally of two magnets which are energized by the main current and act when the current is too high or too low by sending a small current to one of the clutches.

A careful examination of the controller (see Fig. 47), in connection with Fig. 46, will give a clear idea of its regulating action. It is generally advantageous to make the yoke which carries the brushes on the machine and the arm moving the rheostat, rather tight. As the magnetic clutches act with considerable force, it is not necessary to adjust these moving parts so loosely that they will move without considerable pressure on the rocker handle. Less difficulty will then be experienced in adjusting the controller.

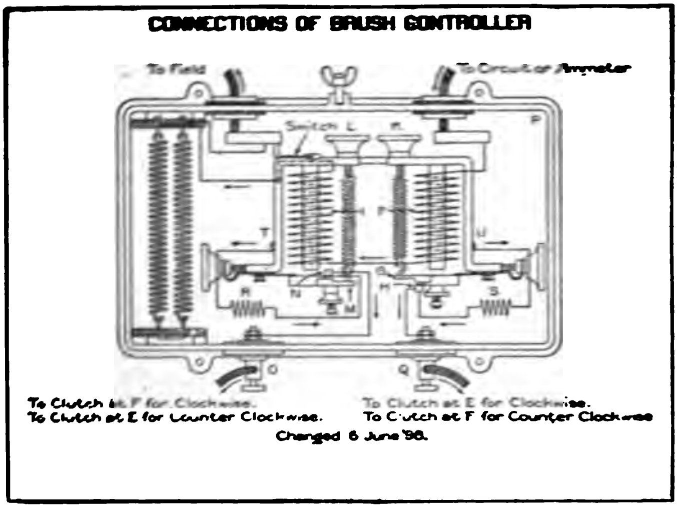

CONNECTIONS OF BRUSH CONTROLLER
To Field
To Circuit or Ammeter
Switch L
R
P
T
U
R
N
M
H
S
O
Q
To Clutch at F for Clockwise.
To Clutch at E for Counter Clockwise.
To Clutch at E for Clockwise.
To Clutch at F for Counter Clockwise
Changed 6 June '98.

FIGURE 47.

For shunt lamps, the controller may be adjusted to permit a variation of .4 ampere above or below normal; for differential lamps, the variation above and below normal should not exceed .2 ampere. The limits given in the following instructions are for differential lamps, and may be extended .2 ampere above or below for shunt lamps.

If the controller is out of adjustment and fails to keep the current normal, do not try to adjust the tensions of both armatures at the same time. For example, suppose the current is too high, either one of the two spools may be out of adjustment. The left-hand spool I may not take hold quickly enough, or the spool F may take hold too quickly. To make the adjustment, screw up the adjusting button K on the right hand spool, increasing the tension. This will have a tendency to let the current fall much lower before the armature comes in contact with H, to cause the current to increase. By simply tapping the armature G quickly with a pencil or piece of wood, forcing it down to its contact, and at the same time watching the ammeter, the current may be brought up to 6.8 amperes if 6.6 amperes is normal, or to 9.8 if 9.6 amperes is normal. With the current at 6.8 amperes, which is .2 ampere high, the adjusting button L should be turned to increase the tension on this spring until the armature M comes in contact with contact N, which will force current down through O. The clutch which pulls the brushes forward and rocks the rheostat back for less current will thus be energized. Repeat this adjustment two or three times, but do not touch the adjusting button K; adjust L until it is just right.

At the side of the armature M a little wedge is screwed in by means of an adjusting button, and increases or decreases the leverage on this armature. See that this wedge is fairly well in between the core or frame of the spool and the spring of the armature. The armature M may have to be taken out and the spring slightly bent. It is advisable to have the screw which passes through the adjuster button L about half way in, to allow an equal distance up and down for adjusting this lighter spring after the wedge shaped piece is in the right position to give the necessary tension on the spring which is fastened to the armature M.

In the right-hand corner P, a small bent piece of wire is placed for tightening up the screw which fastens the spring to the frame of the spool. As the contact made by the spring and the frame of the spool held together by a screw and button is a part of the magnetic circuit, it will be almost impossible to get this spring back to exactly the same tension after once removing it. Therefore, the adjusting buttons of the controller must be turned slightly in order to bring it back to its proper adjustment. This, however, is an after consideration, and care should be taken to have the screw which holds the spring and frame together always tight.

Having adjusted the spool I so that the current will not rise above 6.8 amperes (or 9.8 amperes), move the armature M up to contact N with a pencil or piece of wood, causing the current to be reduced to about 6.2 (or 9.2). After the current settles at this point, decrease the tension on the spring which is fastened to armature G, allowing this armature to fall down to contact H. Current will then flow through Q, which will rock the brushes back and also move the rheostat arm for more current. As the spool I has been adjusted for 6.8 (or

9.8) amperes, the current cannot rise above that amount no matter how the spool F is adjusted.

With very little practice in moving the armature of one spool with a pencil, the other can be adjusted much more readily than if an attempt is made to adjust the screws K and L at the same time.

The two small shunt coils, R and S, are connected around the two contacts simply to decrease the spark between the silver and platinum contacts. If they should become short circuited in any way, so that their resistances become diminished, sufficient current may pass through either of them to operate the regulator. If unable to locate the trouble disconnect these coils at points T and U, when a thorough examination can be made. M and G need not move more than just enough to open the contact; $\frac{1}{32}$ in. is ample.

In starting the machine, the lower switch, which short circuits the field, should be opened last.

The switch in the left-hand corner of the controller, figure 47 cuts out the two resistance wires which are used to force the current through wires O and Q to the clutches. Open this switch, which leaves the automatic device of the controller in circuit, so that it will move the brush rocker. Unclamp the brush rocker from the rheostat arm rocker. Move the brushes by hand to give the proper spark, allowing the rheostat arm, however, to be moved by the controller. After the switches are opened, the rheostat arm will go clear around to a full load position, and then, as the current rises, the controller takes hold and brings the arm back. In the meantime, rock the brushes forward or backward and keep the spark about the proper length, say $\frac{1}{8}$ in., at full load to $\frac{3}{8}$ in., on short circuit. Gradually the rheostat arm will settle, the spark will become constant, and the machine will give its proper current. Then clamp the rocker and rheostat arm together and let the machine regulate itself.

This method is much better than opening the switches on the machine and allowing the wall controller to take care of the machine from the start. By allowing the controller to start the machine, a trifle longer spark is obtained than by the other method, unless the machine is run from the beginning on a very full load.

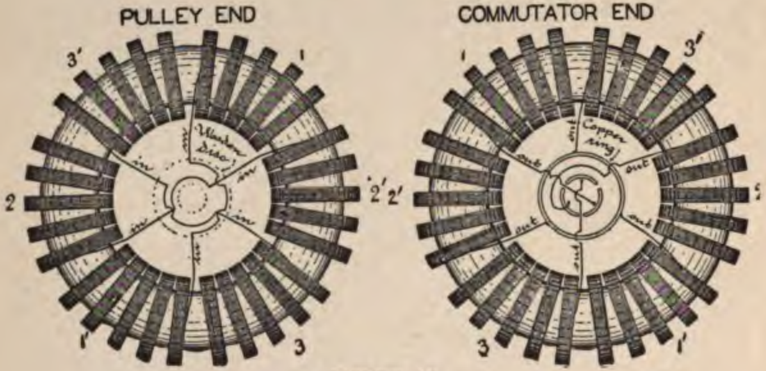


FIGURE 48.

The machine will require a trifle longer spark on light load, or on bad circuits, than when running at full load. This fact should be borne in mind in wet weather, when trouble with grounds is experienced.

A reliable ammeter should always be connected in the circuit of an arc generator, so that the exact current may be read at a glance. It should be connected into the negative side of the line where the circuit leaves the regulator.

The Thomson-Houston System. The Thomson-Houston dynamo differs from other arc dynamos principally in the nature of its armature winding. This is shown in Fig. 48. One end of each of the three coils is connected to a copper ring common to all. The other end of each coil terminates at one of the three commutator segments. The management and operation of the machine will appear from the following instructions taken from pamphlets furnished by the General Electric Company.

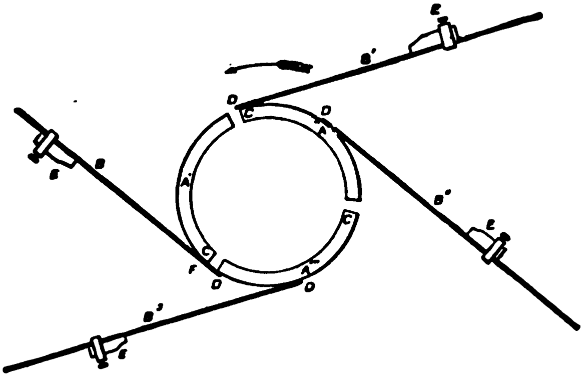


FIGURE 50.

Setting the Cut-out. After the brushes are in position the cut-out must be set. This is done by turning the commutator on the shaft in the direction of rotation (if the commutator is set in position the whole armature must be revolved) until any two segments are just touching the primary brush on that side, as segments A and A''' touch brush B^4 in Fig. 50.

Under these conditions brush B^1 should be at the left-hand edge of upper segment. Then turn commutator until the same two segments are just touching brush B^2, when the end of brush B^3 should just come to the right-hand edge of the lower segment. If the secondary brush projects beyond the edge of the segment the regulator arm should be bent down; if it does not come to the edge of the segment, the arm should be bent up.

Care must be taken that the regulator armature is down on the stop when the cut-out is being set. These adjustments by bending regulator arm are always made in the factory before testing the machine, and should never be made on machines away from the factory, unless the regulator arm has been bent by accident. If it becomes necessary to make any adjustments they should be made by means of the sliding connection attached to the inner yoke.

Always try the cut-out on both primary brushes. If it does not come the same on both, turn one over. If the brush-holders are correctly set by the gauge, there should be no trouble in getting the cut-out set properly after one or two trials.

To set the commutator in the proper position on a right-hand machine, with a ring armature, find the leading wire of No. 1 coil. It is the custom in the factory to paint this lead red, also to paint a red mark on the center band between two groups of coils, namely, the last half of No. 1 coil and the first half of No. 3 coil. The first half of a coil is that group from which the lead comes. The last half is diametrically opposite the first half and the lead wire belonging to it is connected with the brass ring on the outside of the connection disk on the commutator end..

In Fig. 51 the first halves of the three coils are represented by 1, 2 and 3, and the last halves by 1′, 2′ and 3′.

A narrow piece of tin with sharply pointed ends is bent up over the sides of the middle band at the center of the red mark so that the points are opposite each other.

When the red mark and red lead have been found, turn the armature until the last half of No. 1 coil has wholly disappeared under the left field and until the left-hand edge of the first coil to the right of the red mark (No. 3 in Fig. 51) is just in line with the edge of the left field. The red lead will then be in position shown in Fig 51, and the armature is in proper position to set the commutator.

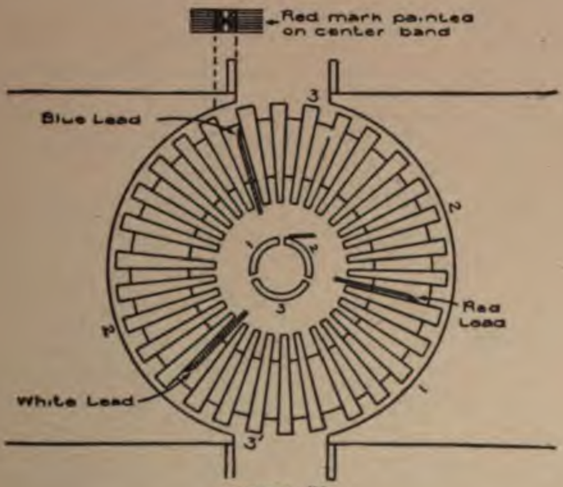


FIGURE 51.

In the case of the right-hand drum armature the leading wire of the first coil should be found. This lead may be recognized from the fact that it is more heavily insulated than the rest, and is found in the center of

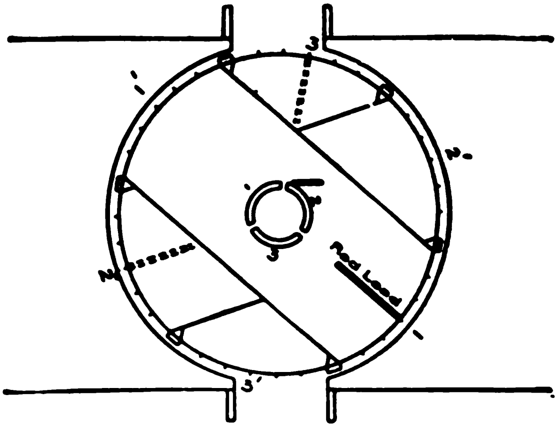


FIGURE 52.

the outer coil, on the commutator end. With this wire turned underneath, rotate the armature forward, or counter-clockwise, until the pegs on the right-hand

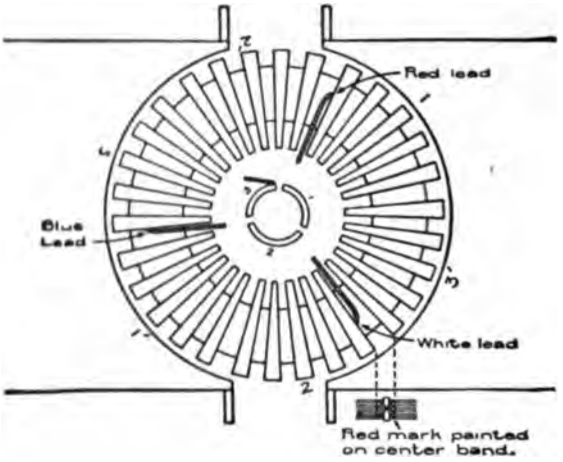


FIGURE 53.

side of this coil just disappear under the left field. (See Fig. 52.)

The position of the red lead and the red mark on the band are the same on all armatures, but their positions in the fields of the machines called left-hand (clockwise rotation), should be as shown in Fig. 53 and 54 when setting the commutator.

When the armature of a right-hand machine is in position, the commutator is turned on the shaft until segment No. 1 is in the same relative position as the last half of No. 1 coil; segment No. 2 should correspond with the last half of No. 2 coil, and segment No. 3 with the last half of No. 3 coil, as shown on Figs. 51 and 52.

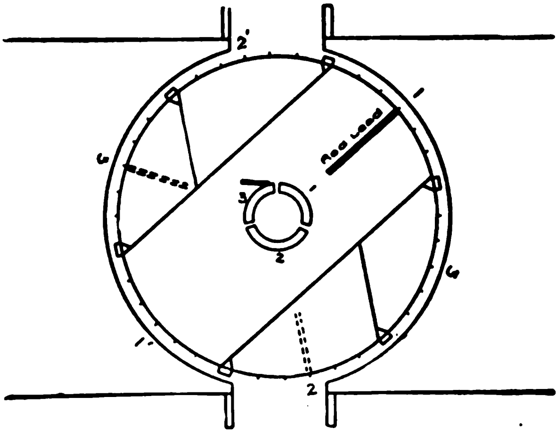


FIGURE 54.

For left-hand machines, see Figs. 53 and 54.

The distance from the tip of the brush, which is on top, to the left-hand edge of No. 2 segment on a right-hand machine, or to the right-hand edge of No. 3 segment in a left-hand machine is called the lead, and should be made to correspond with the following table.

TABLE OF LEADS

DRUM ARMATURES.			
C^{12}	½	inch	positive
C^{2}	½	"	"
E^{12}	$\frac{3}{16}$	"	"
E^{2}	¼	"	"
H^{12}	½	"	"
H^{2}	½	"	"

RING ARMATURES.			
K^{12}	$\frac{3}{16}$	inch	positive
K^{2}	¼	"	"
M^{12}	¼	"	negative
M^{2}	½	"	"
LD^{12}	¼	"	positive
LD^{2}	¼	"	"
MD^{12}	$\frac{11}{16}$	"	"
MD^{2}	$\frac{11}{16}$	"	"

Place the screws in the binding posts at the lower ends of the sliding connections, and put on the dash pot connections between the brushes, with the heads of the connecting screws outward. In every case the barrel part of the dash pot is connected to the top brush-holder, and plunger part to the bottom brush-holder.

See that the field and regulator wires are connected and that all connections are securely made.

When all connections have been made, make a careful examination of screws, joints and all moving parts. They must be free from stickiness and not bind in any position.

To determine when the machine is under full load, notice the position of the regulator armature, which should be within ⅛ in. of the stop. At full load the normal length of the spark on the commutator should be about $\frac{3}{16}$ in. If it is less than this, shut down the machine and move the commutator forward or in the direction of rotation until the spark is of the desired length. If the spark is too long, move the commutator back the proper amount.

A general view of the complete dynamo is given in

Fig. 55, and will help explain the regulator used with this system.

The regulator is fastened to the frame of the machine by two short bolts. On the right-hand machine its position is on the left-hand side, as shown in Fig. 55. On the left-hand machine, *i.e.*, one which runs clockwise, its position is on the opposite side. Before filling the dash pot D with glycerine, see that the regulator lever and its connections, brush yokes, etc., are free in every joint, and that the lever L can move freely up and down. Then fill the dash pot D with concentrated glycerine. The long wire from the regulator magnet M is connected with the left-hand binding post P of the machine, and the short wire with

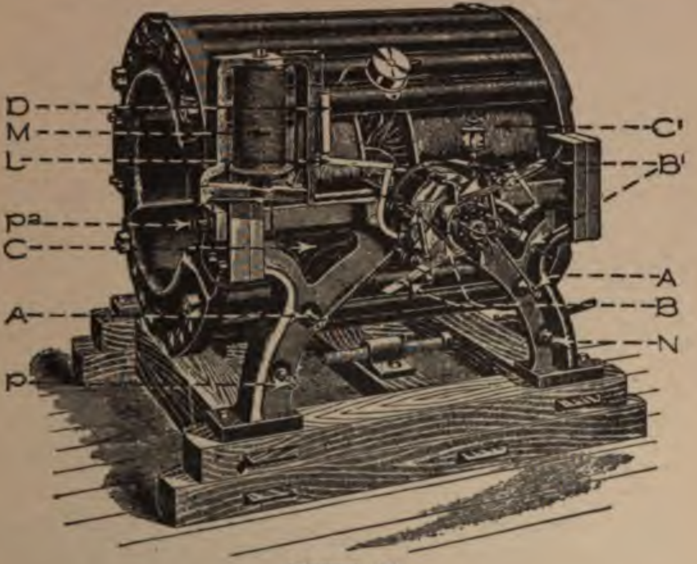


FIGURE 55.

the post P^2 on the side of the machine. The inside wire of the field magnet, or that leaving the iron flange, of the left-hand field should be connected into post P^2 also, as shown in Fig. 55. The electric circuit (see Fig. 56) should be complete from post P^1, on the controller magnet, through the lamps to the post N on the machine, through the right-hand field magnet C, to the brushes B^1B^1, through the commutator and armature to the brushes B B, through the left-hand field C, to posts P^2 and P, thence to posts P^2 and P on the controller magnet, through the controller magnet to P^1. The current passes in the direction indicated by the arrows

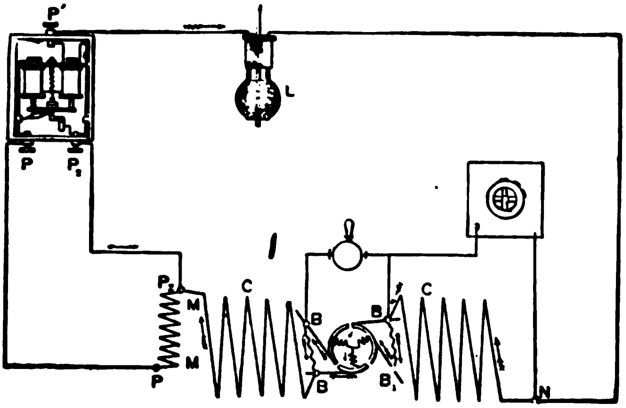


FIGURE 56.

When an arc machine is to be run frequently at a small fraction of its normal capacity, the use of a light load device is advisable to secure the best results in regulation.

The rheostat for this purpose (see Fig. 57) is connected in shunt with the right field of the generator.

Facing the rheostat with the right binding posts at the bottom, the contact on the right side or No. 1 gives open circuit and throws the rheostat out of use. Point No. 2 gives a resistance of 44 to 46 ohms and Point No. 3 gives a resistance of 20 to 22 ohms.

This rheostat with a 75-light machine allows the following variations: Point 1, 75 to 48 lights; Point 2, 48 to 25 lights; Point 3, 25 lights or less. For use with other sizes of generators, the adjustment of the rheostat must be made to suit the conditions.

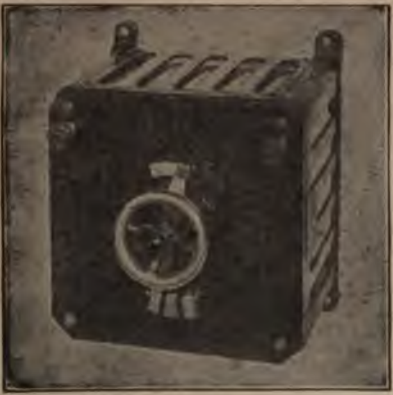


FIGURE 57.

When the rheostat is in use, the sparks at the commutator will be somewhat larger than normal, but will not be detrimental.

The controller magnet (see Fig. 58) is to be fastened securely by screws to the wall or some rigid upright support, taking care to have it perfectly plumb. It is connected to the machine in the manner shown in Fig. 55, *i.e.*, the binding post P^2 on the controller magnet is connected to the binding post P^2 (see Fig. 55) on the end of the machine, and likewise the post P on the controller to the post P on the leg of the machine; the post P^2 forms the positive terminal from which the circuit is run to the lamps and back to N.

Great care should be taken to see that the wires P P

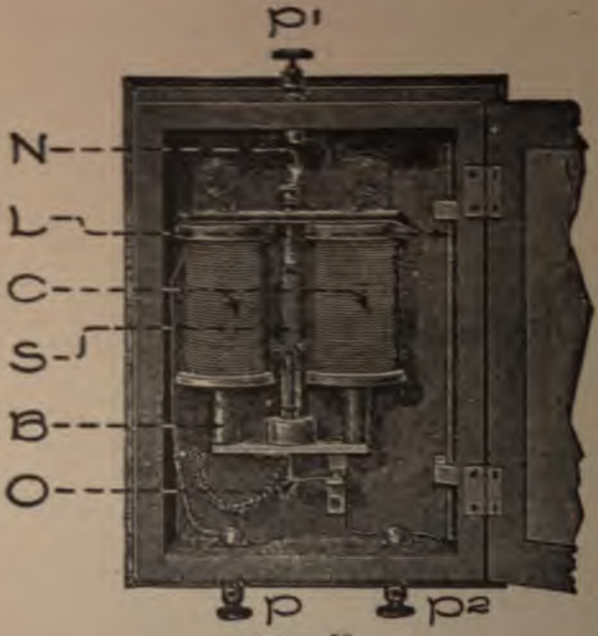


FIGURE 58.

and P^2 P^2 are fastened securely in place; for if connection between P and P should be impaired or broken, the regulator magnet M would be thrown out of action, thus throwing on the full power of the machine, and if the wire P^2 P^2 should become loosened, the full power of the magnet M would be thrown on, and the regulator lever L, rising in consequence, would greatly weaken or put out the lights.

The wires leading from the controller magnet to the machine should have an extra heavy insulation.

Care should be taken in putting up the controller magnet that the following directions are followed:

1. The cores B of the axial magnets C C must hang exactly in the center, and be free to move up and down.

2. The screws fastening the yoke or tie pieces to the two cores must not be loosened.

3. The contacts O must be firmly closed when the cores are not attracted by the coils C C, which is the case, of course, when no current is being generated by the machine, and when the cores are lifted, the contacts must open from $\frac{1}{64}$ in. to $\frac{1}{32}$ in.; a greater opening than $\frac{1}{32}$ in. has the effect of lengthening the time of action of the regulator magnet. This tends to render the current unsteady, and in case of a very weak dash pot or short circuit might cause flashing. Adjustment must be made if necessary by bending the lower contact up or down, taking care that it is kept parallel with the upper contact, so that when they are closed, contact will be made across its whole width. If this adjustment is not properly made there will be destructive sparking on a small portion of the contact surfaces.

4. All connections must be perfectly secure.

5. The check nuts N must be tight.

6. The carbons in the tubes L must be whole. These carbons form a permanent shunt of high resistance around the regulator magnet M, and if broken will cause destructive sparking at contacts O, burning them and seriously interfering with close regulation of the generator. In case a carbon should become broken,

temporary repairs may be made by splicing the broken pieces with a fine copper wire.

To keep the action of the controller perfect the contacts O should be occasionally cleaned by inserting a folded piece of fine emery cloth and drawing it back and forth.

The amount of current generated by each machine depends upon the adjustment of the spring S. If the tension of this spring is increased the current will be diminished; if the tension is diminished, the current will be increased.

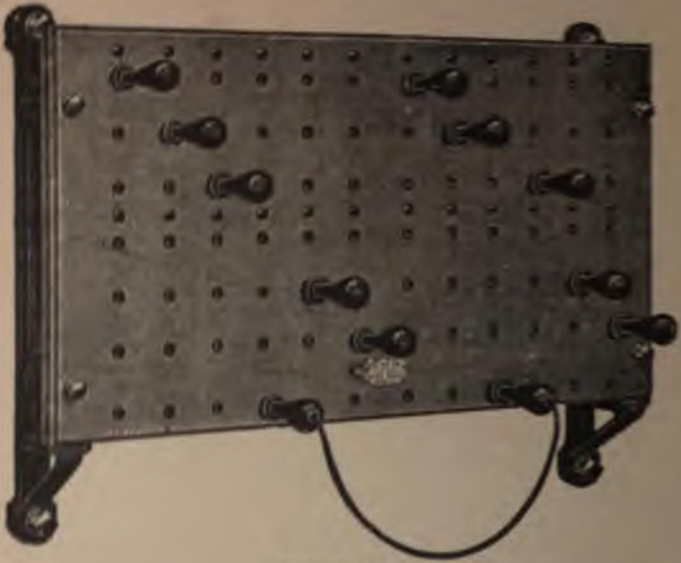


FIGURE 59.

In starting these dynamos when the armature has reached its proper speed, the short circuiting switch on the frame should be opened. This method allows the generator to take up its load gradually, and is a very important point in the handling of the machine.

Arc Switchboards. Fig. 59 shows a general view of the Thomson-Houston plug switchboard. A rear view of the same board is given in Fig. 60.

In a standard panel the number of horizontal rows of holes equals one more than the number of generators. The vertical holes are always twice the number of generators. The positive leads of the generators are attached to the binding posts on the left-hand ends of the horizontal conductors. The negative leads are connected to the corresponding binding posts at the right-hand end of the board.

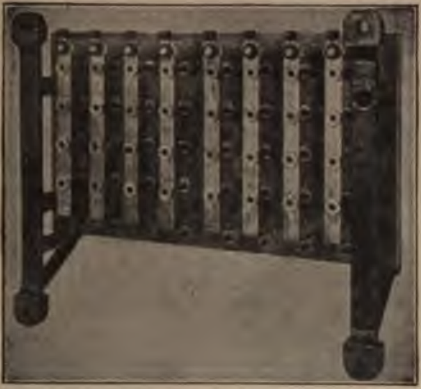


FIGURE 60.

The positive line wires are connected to the vertical straps on the left, and the negative wires to the similar straps on the right of the center panel.

If a switchboard plug be inserted in any of the holes of the board, it puts the corresponding generator lead and the line wire in electrical connection, but as the positive line wires are back of the positive generator leads only, it is not possible to reverse the connection of the line and the generator accidentally, though any other combinations of lines and generators can be made readily and quickly.

The holes of the lower horizontal rows have bushings connected with the vertical straps only. Plugs connected in pairs by flexible cable and inserted in the holes put the corresponding vertical straps in connection as needed, and normally independent lines may be connected when one generator is required to supply several circuits.

Lines and generator leads may be transferred, while running, by the use of these cables, without shutting down machines or extinguishing lamps.

The standard boards are arranged for an equal number of generators and circuits, but special boards for any ratio of circuits to generators can be built.

As it is sometimes convenient, even in small plants, to interchange lines and generators without shutting down machines, a special transfer cable with plugs has been devised. This serves the same purpose as the regular transfer cable, but the plugs may be used in any of the holes of the switchboard, as they are insulated, except at the tip, and when inserted connect with the line strips only.

The transfer of circuits from one generator to another gives trouble to dynamo tenders who are not familiar with the operation of these plug switchboards. Fig. 61 illustrates the successive steps for transferring the lamps of two independent circuits from two generators to one without extinguishing the lamps on either circuit.

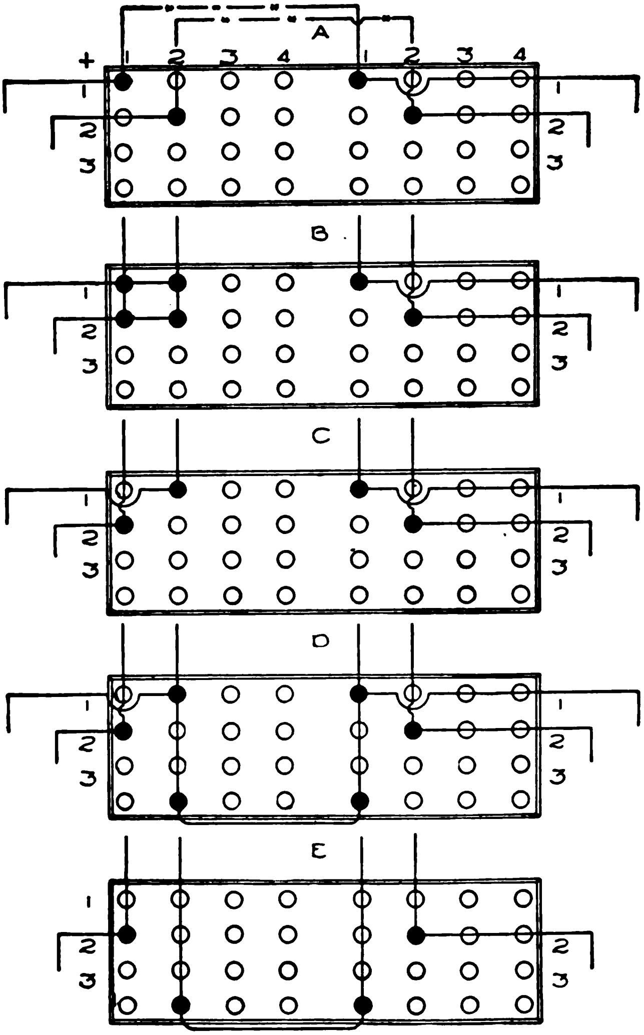


FIGURE 61.

This process is a very simple example of switchboard manipulation, but illustrates the method used for all combinations.

The location of plugs is shown by the black circles, which indicate that the corresponding bars of the horizontal and vertical rows are connected.

Circuit No. 1 and No. 2 running independently from generators No. 1 and No. 2 respectively, are to be transferred to run in series on generator No. 2.

In A, Fig. 61, are two circuits running independently; in B the positive sides of both generators and circuits are connected by the insertion of additional plugs.

At C both generators and circuits are in series.

Next insert plugs and cables as shown in D. Then withdraw plugs on row corresponding to generator No. 1, and the circuits No. 1 and No. 2 are in series on machine No. 2, and machine No. 1 is disconnected as at E.

Similar transfers can be made between any two circuits or machines, and by a continuation of the process additional circuits can be thrown in the same machine. The transfer of the two circuits to independent generators is accomplished by reversing the process illustrated.

Fig. 62 shows the wiring and connections of the Western Electric Co.'s series arc switchboard. At the top of the board are mounted six ammeters, one being connected in the circuit of each machine. On the lower part of the board are a number of holes, under which, on the back of the board, are mounted spring jacks to which the circuit and machine terminals are connected. For making connections between dynamos and circuits, flexible cables terminating at each end in a plug, are used; these are commonly called "jumpers." The board shown has a capacity of six machines and nine circuits, and with the connections as shown machine 1 is furnishing current to circuit 1, machine 2 is furnishing current to circuits 2 and 3, and machine 4 is furnishing current to circuits 4, 5 and 7. In connecting together arc dynamos and circuits the positive of the machine (or that terminal from which the current is flowing) is connected to the positive of the circuit (the terminal into which the current is flowing). Likewise the negative of the machine is connected to the negative of the circuit. Where more than one circuit is to be operated from one dynamo, the – of the first circuit is connected to the + of the second. At each side of the name plate (at 3, for instance) there are three holes. The large hole is used for the permanent connection, while the smaller holes are used for transferring circuits, without shutting down the

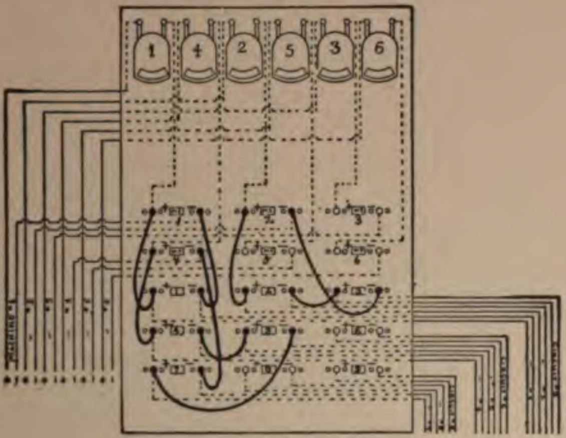


FIGURE 62.

dynamo. Smaller cables and plugs are used for transferring. If it is desired to cut off circuit 5 from machine 4, a plug is inserted in one of the small holes at the right of 4, the other plug being inserted in one of the holes at the left of 7. Circuit 5 would now be short circuited, and the plug in the + of 5 can now be transferred to the permanent connection in the + of 7, and the cords running to 5 removed. If it is desired to cut in a circuit, say circuit 6 onto machine 2, insert a cord between the – of circuit 2 and the + of 6 and another between the – of 6 and the + of 3. Now pull the plug on the cord connecting – of 2 and the + of 3 and insert the permanent connections. In cutting in circuits, if they contain a great number of lights, a long arc may be drawn when the plug between 2 and 3 is pulled, and it is sometimes advisable to shut down the machine when making a change of this kind.

CHAPTER V

MOTORS.—ALTERNATING CURRENT MOTORS.

Motors. Any dynamo may be used as a motor and consequently we have as many types of motors as there are types of dynamos. The pull of a motor depends upon the repulsion and attraction between the lines of force, or magnetism of the wire and core of the armature and that of the fields. We have seen that in a dynamo, as we force a wire through a magnetic field, current is generated. The more current there is generated or flowing in such a wire, the greater will be the expenditure of power necessary to force such a wire through a magnetic field; in other words, the currents flowing in the wires of a dynamo armature, always tend to drive the armature in a direction opposite to that in which it is being driven.

If, then, instead of revolving a dynamo armature by mechanical means, we connect it to a source of electricity and allow a current to flow through it we must obtain motion, and the direction of this motion will depend upon the direction in which the current flows, so long as this current does not alter the magnetism of the fields.

We have already seen that the electric motor is built exactly like a dynamo; consequently, as its armature revolves it not only does useful work, such as turning whatever machinery it is belted to, but it also generates an electromotive force. For instance, if a motor, running at full speed and receiving current from a dynamo (Fig. 63), were suddenly disconnected by opening the main switch, it would at once begin acting as a generator and sending out current. This can be easily seen with any motor equipped with a starting box, such as shown; for the current from the motor will continue to energize the fields and the little magnet M so as to hold the arm of the starting box until the motor has nearly come to rest. If it were not for the current generated by the motor, this arm would fly back the instant the switch is opened.

The electromotive force set up by a motor always opposes that of the dynamo driving it; that is, the current which the motor tends to send out would flow in the opposite direction to that which is driving it.

This may be compared, and is somewhat similar, to the back pressure of the water which a pump is forcing into a tank. If the check valves were removed and the steam pressure shut off, the water would tend to force the pump backward.

This electromotive force is called the counter electromotive force of the motor. The counter electromotive force of the motor varies with the speed of the motor and also limits the speed of the motor, for it is obviously impossible that a motor should develop higher counter E. M. F. than the E. M. F. of the dynamo driving it.

This highest possible speed of a motor is, then, that speed at which its counter E. M. F. becomes equal to the E. M. F. of the dynamo supplying the current, and this is the speed which would be obtained were the motor doing no work and running without friction. This condition is impossible in practice, and the counter E. M. F. of the motor is always less than the E. M. F. of the dynamo. In order to speed up a motor we must arrange it so that it must run faster in order to develop an E. M. F. equal to that of the dynamo; we can do this by lessening the number of turns of wire on the armature, or by lessening the magnetism of the fields. In doing so, however, we also lessen the capacity of the motor for performing work.

The power that can be obtained from an electric motor depends upon two things: the current flowing in its armature coils and the strength of magnetism developed in the fields.

Assuming the fields as remaining constant, the power of the motor must then vary as the current flowing through it. Suppose we have a motor being driven by an E. M. F. of 110 volts and it is doing no work; it will be running at full speed and its counter E. M. F. will therefore also be very near 110 volts. If now a load be thrown on this motor, it must get more current in order to develop the necessary power to carry the load.

Throwing on the load will decrease the speed of this motor, and consequently its counter E. M. F. will fall, say to 100 volts. The E. M. F. of the dynamo being 110 and the counter E. M. F of the motor 100, there will be considerable current forced through the armature of the motor, so that it can now handle the load.

The current in the armature at all times will equal $\frac{E - E'}{R}$ where E is the electromotive force of the dynamo, E' the counter electromotive force of motor, and R the resistance of the motor armature. In order that a motor should keep a nearly uniform speed, for varying loads, the resistance of its armature should be very low, for then a slight drop in counter E. M. F.

will allow considerable current to flow through the armature. The above applies particularly to the shunt motor shown in Fig. 63. In this diagram C is a double pole fuse block, S the main controlling switch, R the starting box, or rheostat, M the magnet, which holds the arm of the starting box in place when it is brought over against it, F the fields, and A the armature of the motor.

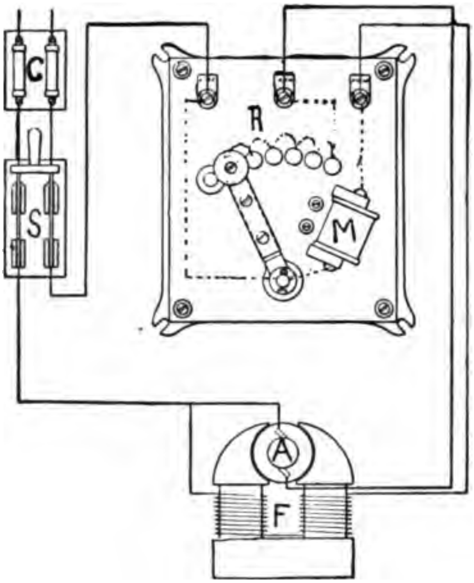


FIGURE 63.

The current enters, say at the right hand fuse, and passes to the starting box and along the fine wires shown in dotted lines through the fields of the motor and coil M to the other fuse The fields of the motor and the little magnet M are now charged, but as yet there is no current passing through the armature and no motion. We now slowly move the arm on the starting box to the right; this admits a little current, limited by the resistance in the starting box, to the motor armature and it begins to revolve, and as we continue to move the arm to the right, the armature gains in speed because we admit more current to it by cutting out more and more resistance. When the armature attains full speed, the arm comes in contact with the little magnet M, and is held there by magnetism. The whole object of the starting box is to check the inrush of current, while the armature is developing its counter E. M. F. or back pressure.

When the armature has attained its normal speed, the starting box is no longer in use. If for any reason the current ceases to flow, the little magnet M loses its magnetism and releases the arm, which (actuated by a spring) flies back and opens the circuit so that, should the current suddenly come on again, the sudden inrush will not damage the armature.

In Fig. 64 are shown the connections of a series wound motor with an automatic release spool on the starting box of a sufficiently high resistance so it can be connected directly across the circuit. This becomes necessary since the field windings are in series with the armature.

The speed of a series motor may be decreased by connecting a resistance in series with the motor and may be increased in speed by cutting out some of the field windings. In electric railway work where two motors are used on one car, they are usually connected in series with each other in starting up and then in parallel with each other while running at full or nearly full speed. The series motor is well adapted to such work as electric railway work, or for cranes and so forth, because it will automatically regulate its speed to the load to be moved, exerting a powerful torque at a low speed while pulling a heavy load. Such a motor, however, requires constant attendance when the load becomes light, as it will tend to "run away" unless its speed is checked.

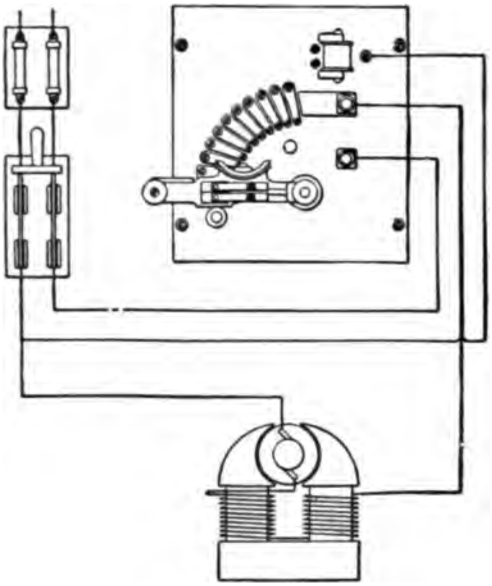


FIGURE 64.

In Fig. 65 we have a diagram of a compound wound motor connected with a type of starting box that cuts out the armature when current has been cut off the lines supplying the motor, as before explained. In addition to this there is another electro magnet which is traversed by the main current on its path to the armature. Should the motor be overloaded by some means, the current flowing to the armature would exceed the normal flow. The magnetism thus produced would overcome the tension of a spring on the armature of the so-called "overload magnet" and cause it to short circuit the magnet which holds the resistance lever and allow it to fly back and open the armature circuit. By so doing the liability of burning out the armature due to overload is reduced to a minimum.

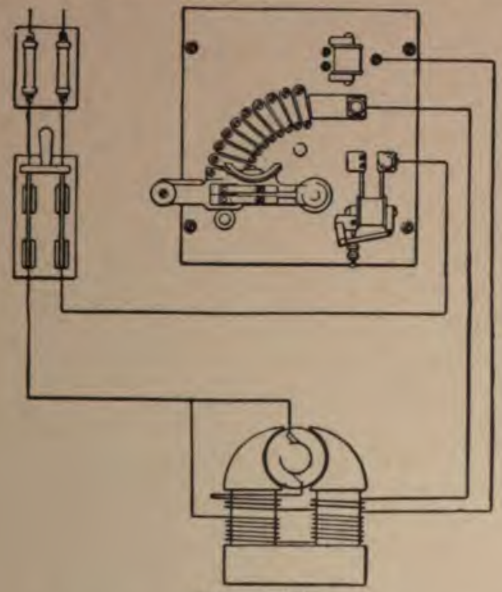


FIGURE 65.

The compound motor may be made to run at a very constant speed, if the current in the series winding of the fields is arranged to act in opposition to that of the shunt winding. In such a case an increase in the load of a motor will weaken the fields and allow more current to flow through the armature without decreasing the speed of the armature, as would be necessary in a shunt motor. Such motors, however, are not very often used, since an overload would weaken the fields too much and cause trouble.

If the current in the series field acts in the same direction as that of the shunt fields, the motor will slow up some when a heavy load comes on, but will take care of the load without much trouble. Fig. 66 shows a starting box arranged as a speed controller. It differs from other starting boxes only in so far that the resistance wire is much larger and that the little

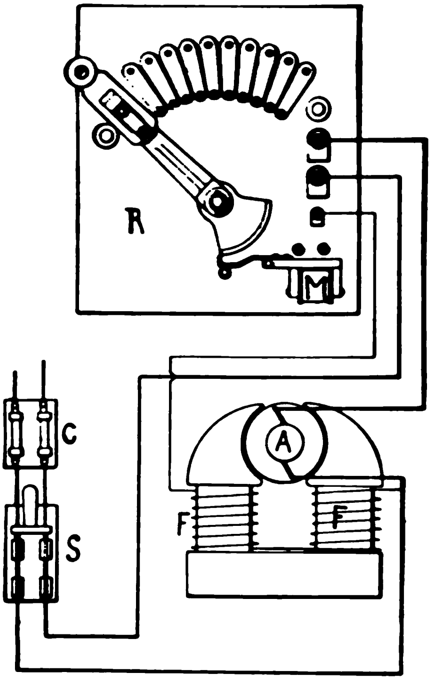


FIGURE 66.

magnet will hold the arm at any place we desire, so that if we leave the arm at any intermediate point the motor will run at reduced speed. This sort of speed regulation can be used only where the load on the motor is quite constant. If the load varies, the speed will vary. Another and a better way of varying the speed of motors consists in cutting a variable resistance into the field circuit, as more resistance is cut into the circuit the fields become weaker and the motor speeds up. If possible, motors should be so designed that they can operate at their normal speed, and they will then cause little trouble.

Motors have much the same faults as dynamos, but they make themselves manifest in a different way. An open field circuit will prevent the motor from starting and will cause the melting of fuses or burning out of an armature. The direction of rotation can be altered by reversing the current through either the armature or the fields. If the current is reversed through both, the motor will continue to run in the same direction. A short circuit in the fields, if it cuts out only a part of the wiring, will cause the motor to run faster and very likely spark badly. If the brushes are not set exactly opposite each other, there will also be bad sparking. If they are not at the neutral point, the motor will spark badly; brushes should always be set at the point of least sparking. If it becomes necessary to open the field circuit, it should be done slowly, letting the arc gradually die out; a quick break of a circuit in connection with any dynamo or motor is not advisable, as it is very likely to break down the insulation of the machine.

The ordinary starting box for motors is wound with comparatively fine wire and will get very hot if left in armature turns. The movement of the arm from the first to the last point should not occupy more than thirty seconds, and if the armature does not begin to move at the first point the arm should be thrown back and the trouble located.

Alternating Current Motors. By a proper combination of two phase or three phase currents it is possible to produce a revolving magnetic pole. By placing inside of the apparatus which produces this revolving magnetic pole a suitable short circuited armature, this armature will be dragged around by the revolving pole in much the same way that a short circuited armature in a direct current field would be dragged around if the fields were revolved. Such a machine is called an induction motor. The armature will revolve without any current entering it from the external circuit. This does away with commutators, collector rings, brushes, brush-holders, and in fact many of the parts which are so necessary in direct current machines. The rapidity of the alternations in the external circuit determines the speed of the motor.

Some alternating current motors are known as "synchronous motors." What is meant by synchronous is, occurring at the same time, or in unison. As an example, suppose two clocks are ticking just alike so that the pendulums start and stop at the same time; we would hear but one tick. These two clocks would then be in synchronism. If an alternating current generator has 32 field coils and revolves at the rate of 60 R. P. M., then a synchronous motor with only 4 field coils would revolve at the rate of 480 R. P. M. This motor would operate in synchrony with the generator and yet would make 480 R. P. M. while the generator made 60 R. P. M.

CHAPTER VI

Fuses and Circuit Breakers. Fuses are metal wires or strips, generally made of an alloy of lead and antimony, the amount of each metal used being so proportioned that the wire will melt at a certain temperature. This metal is very similar to that used in the fusible plugs in boilers. These fuse strips or fuse wires are placed in the various circuits in such a manner that the current must first flow through the fuse before entering the lights, motors or other electrical apparatus. If a short circuit should occur, there would be an excessive amount of current flow through the fuse and the temperature of the metal would be raised to the point where it would melt and open the circuit. This would cut off the current and save the electrical apparatus from being damaged by the excessive current. Fuses are placed in the various circuits in accordance with the rules and regulations of the National Board of Fire Underwriters. These rules require a fuse to be placed in the circuit of every piece of electrical apparatus liable to be short circuited, and also at points where small wires are tapped onto larger ones, unless the main fuse in the larger wire is small enough to protect the smallest wire in the circuit. The ordinary commercial fuse wire is not intended to melt until the current has reached a strength of about twice the number of amperes marked on the fuse. A few good points to remember in regard to fuses are as follows: Unless the fuses are of the new enclosed type (fuses entirely encased in small tubes) or unless they are under the eye of a constant attendant, they should be enclosed in fireproof boxes. This should be done to minimize the chance of the red hot metal from a melted fuse dropping into some inflammable material. It is a very good plan to enclose all fuses. Fuses placed in a hot room will blow at a lower increase in current than those in a cool room. Always use copper tipped fuses, both for the purpose of getting a good contact at the binding screw and for the reason that the blowing point of a fuse wire depends on the length of the wire. Two pieces of fuse wire of the same diameter, but of different lengths, will not blow with the same current because the cooling effect of the terminals is greater with the shorter fuse.

In the larger size fuse strips see that the contacts between the fuse terminal and the binding post are free from dirt and that there is plenty of contact between them, otherwise the poor contact will heat up the terminal and the fuse strip and cause it to blow at a much lower current strength than that for which it is marked. Oil between the contacts will cause heating and the same result.

From the fact that when a fuse strip has blown the current will be off the circuits which are protected by the strip until the fuse has been replaced, and this takes some time, another device known as the circuit breaker has come into general use. The circuit breaker is simply a knife switch equipped with a spring which tends to open it, and is held in place by a small catch. The current passing through the switch also passes through the winding of a small solenoid on the inside of which is an iron core. When the current passing through the solenoid exceeds a certain amount, the iron core is drawn up into the solenoid, and in doing so strikes the catch holding the switch and releases it, thus opening the switch and cutting off the current. Circuit breakers are nearly always installed in the cir-

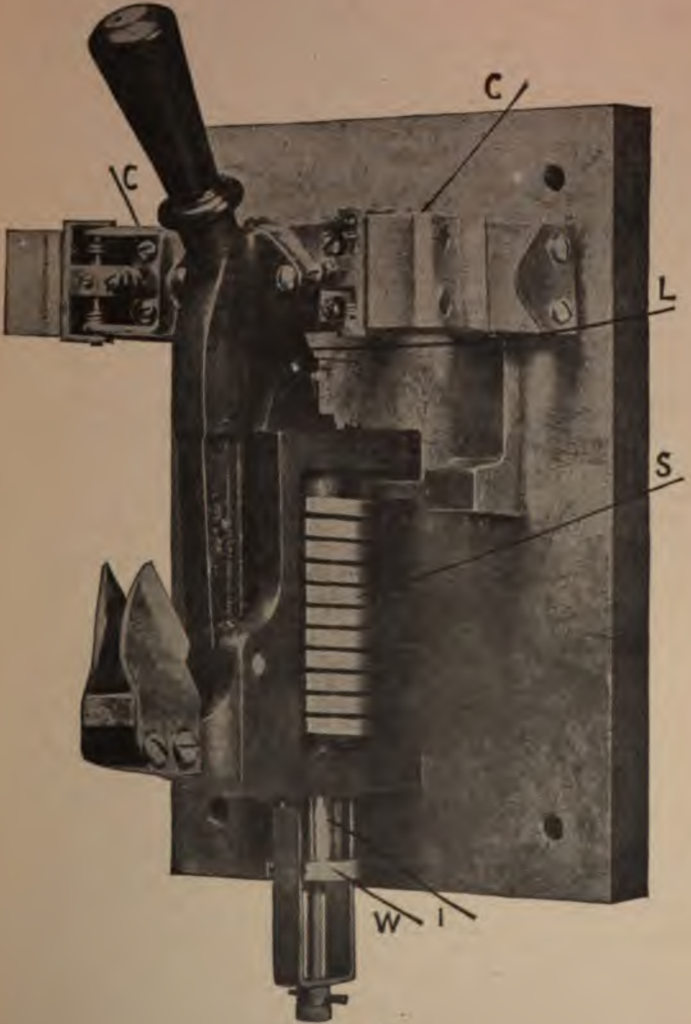


FIGURE 67.

cuits of generators, although fuses are also used. The fuse is rated higher than the circuit breaker, so that the circuit breaker will operate first and the fuse only operates when the circuit breaker fails to work. Circuit breakers are also used to a large extent in protecting large motors, and the small overload devices used on motor starting boxes are simply circuit breakers. Fig. 67 shows a view of an I-T-E circuit breaker. S is the solenoid and I the moveable iron core. This core is adjustable, by means of the washer W, so that it will operate at whatever current desired. L is the catch which holds the switch. Carbon contact pieces, C C, are so arranged that the current is broken on them, thus taking the arc off the blades. In Fig. 68 a diagram of a circuit breaker used for the protection of a motor is shown. In this case the circuit breaker is double pole; while the one shown in the preceding figure is single pole.

For small work, such as tap lines and small motors, the circuit breaker is too expensive to warrant its use, but for capacities of 50 amperes and over it is advisible to use the circuit breaker. Circuit breakers are also designed and used to prevent the liability of short circuits between generators connected in parallel, due to the reversal of polarity of one of the dynamos. In other words, should one of the dynamos become reversed in polarity while working in parallel with other machines, the polarity circuit breaker would open the machine-switch and cut it out. Circuit breakers of this description are also used in charging storage batteries. Sometimes circuit breakers are referred to as overload switches. The mechanical operation of these instruments can be readily understood when examined, as they are all of a very simple mechanical construction.

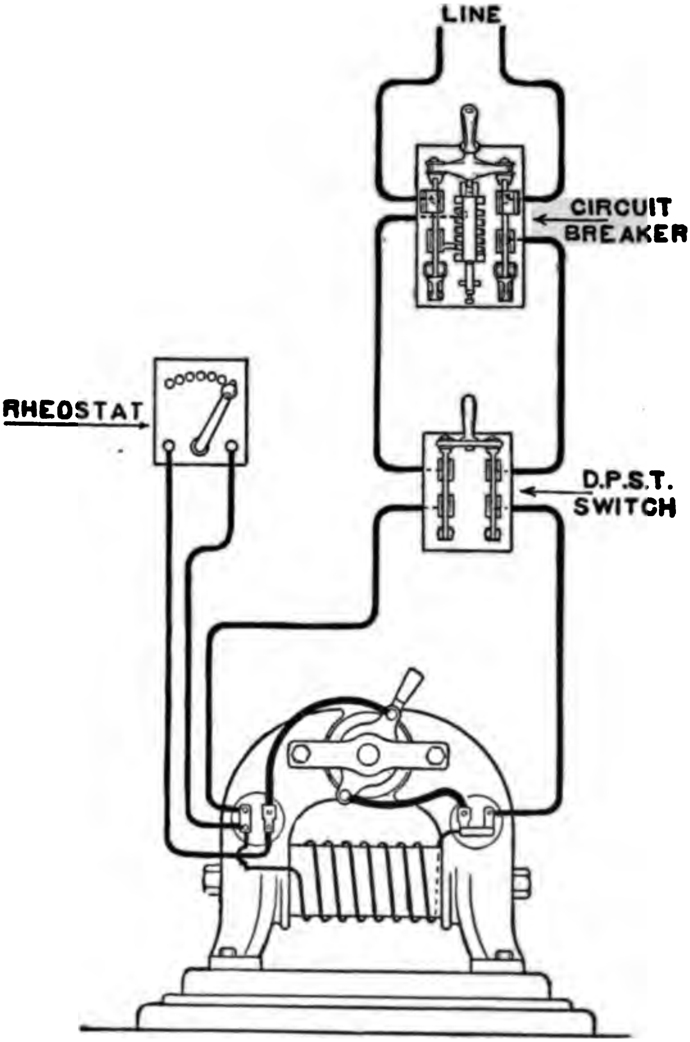


FIGURE 68

CHAPTER VII

ALTERNATING CURRENT DYNAMOS

Alternating current dynamos are operated upon the same general principle of magnetic induction as that involved in continuous current dynamos. The mechanical construction, however, differs considerably in the two types of machines. The current produced in the two types is identical, but in the direct current machine this current is rectified by means of a commutator; that is, the current constantly flows out one wire and back in the other wire, never changing in direction in the external circuit. In the alternating current dynamo the current is sent to the line exactly as it is generated in the armature, flowing out one wire and back on the other and then reversing and flowing out on the wire on which it has just flowed in, and back on the wire on which it had formerly flowed out. An illustration which will more fully explain this action can be found by supposing the two ends of the cylinder of a piston pump were connected by means of a pipe and then, having done away with all the valve movements, the pumps were started. At the beginning of the stroke, water would be forced out one side of the cylinder around the pipe into the other side of the cylinder, and after the piston had reached the end of the stroke and started back, the water would then take a return course back to where it had started. In this case the pump could be likened to the dynamo and the pipe to the wires, and the current to the water flowing back and forth. The form and winding of alternating current dynamos varies considerably, but they generally follow the plan shown in Fig. 69. In the figure the pole pieces are alternately north (N) and south (S), while the armature is wound with the same number of poles, with the winding so arranged that the poles alternate. The fields are excited by direct current passing over the field coil windings. This direct current is usually obtained from another source aside from the current generated in the armature of the alternating current dynamo. A separate dynamo, called an exciter, is employed for supplying the current to the fields. There are some types of so called "composite wound alternating current dynamos" in which a part of the current from the alternator arma-

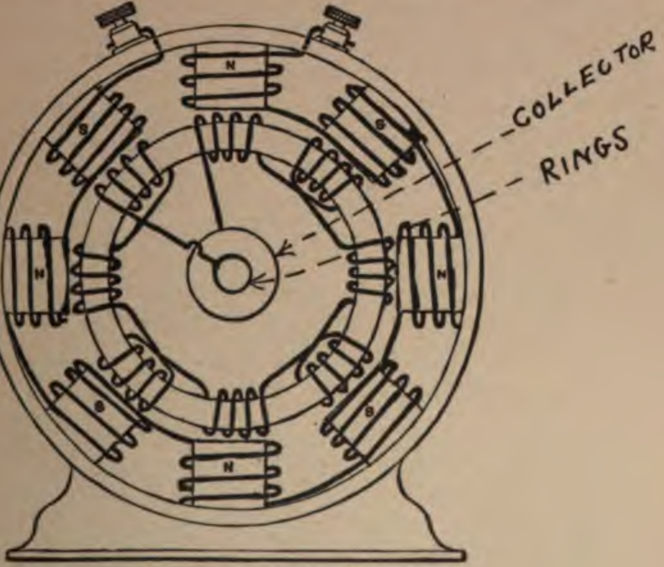


FIGURE 69.

ture is rectified or commutated by means of a commutator mounted on the same shaft with the armature, and this commutated current passed around the field coils in a manner similar to the direct current com-

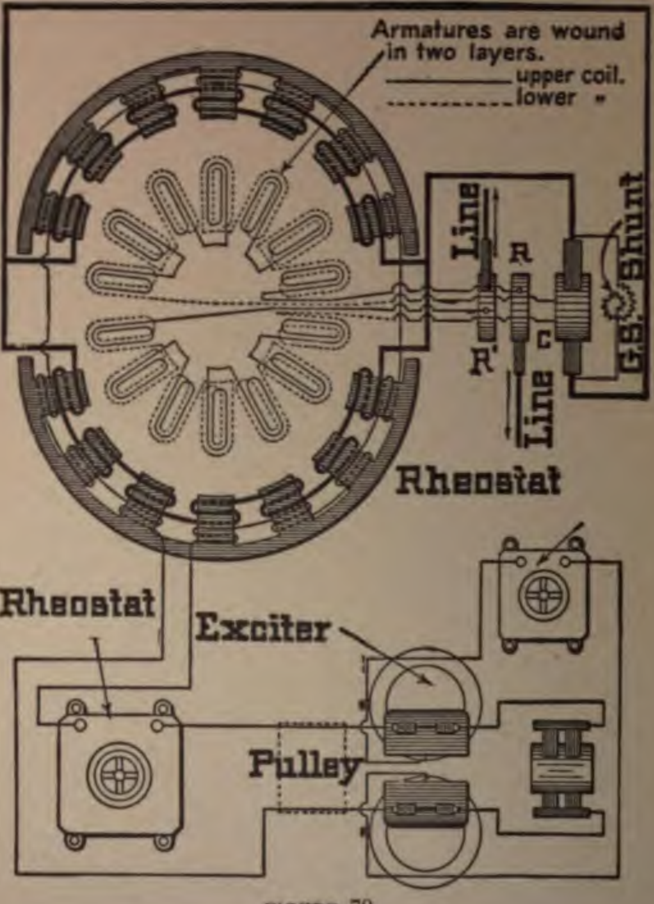


FIGURE 70.

pound wound dynamo. In Fig. 70 we have a diagram of connections of a composite wound machine made by the General Electric Company. It will be noticed that in connection with this dynamo we still employ a separate direct current exciting machine. The object of this composite winding is the same as with the compound wound direct current dynamo, namely, regulation under variable loads without the necessity of changing the strength of the field exciting current from the exciter dynamo. The winding of the alternate current armature consists of the same number of armature coils as there are pole pieces in the fields of the machine. The outer end of the first armature coil is left free to be connected to one of the collector rings, while the other end of the coil is connected to the inner end of the second coil; the outer end of the second coil is connected to the outer end of the third coil, and so on through the entire armature. In this class of winding you can readily see that while the coils connected from the underside or inner ends are under the influence of one polarity of field magnetism, the armature coils connected from the outer side are under an opposite magnetic influence. The purpose of forming the armature circuit in this manner may be fully understood when it is remembered that the magnetism from the north pole of a magnet will induce a flow of electricity in a coil of wire in a given direction, while the magnetism of the south pole will induce a flow of current in an opposite direction. Now, for the reasons just explained, the current in all of the coils of the armature will flow in the one direction, but as the armature is rotated sufficiently to move the coils from the influence of one pole to the influence of the opposite pole which is next to it, the action of all the magnetic poles of the field reverse all the inductions in the armature coils and cause the current to flow in an opposite direction. The number of reversals occurring during a revolution is determined by the number of poles that the armature coils pass during one revolution. One of these armature coils we will assume to be under a north magnetic influence and in its rotation it passes through a south magnetic influence, thence into a north magnetic influence again. The current has now alternated or reversed its direction of flow twice and has passed through what is called one cycle. If the current were making 120 alternations or passing through 60 cycles in one second, it would be known as making 60 cycles or alternating at the rate 7,200 alternations per minute. These are the general terms used in designating alternating currents.

By tracing out the circuits in Fig. 70, it will be seen tnat, assuming the current to be flowing into the collector ring R, it will pass through the upper half of the armature winding and out to the commutator C, where a part of it will be commutated (or changed into direct current), then flowing back around the lower half of the armature windings and out to the other collector ring R′. On the commutator C the upper line coming from the armature is connected to each alternate segment, while the lower line is connected to the remaining segments. The amount of current which is thus rectified and flows around the two halves of the field winding, which are connected in parallel, is regulated by means of the German silver shunt. The fields are also energized by the current generated in the small dynamo known as the exciter.

In Fig. 71 is shown an alternating current dynamo with its separate exciter The two collector rings are shown immediately at the right of the armature, while at the right of the collector rings is shown the commutator from which the current for the composite winding of the fields is taken. The current generated by the alternator is regulated in the same way as with direct current dynamos; that is, by varying the current sent around the field windings. This is accomplished by the use of a resistance box in series with the exciting current or by means of a resistance box connected in the fields of the exciting dynamo. This latter regulation is of course the more economical, as there would be considerable energy wasted were a resistance used in the main exciting circuit. Alternating currents are generally used where currents are to be transmitted long distances, as for instance, where power is derived from a water fall situated some distance from the

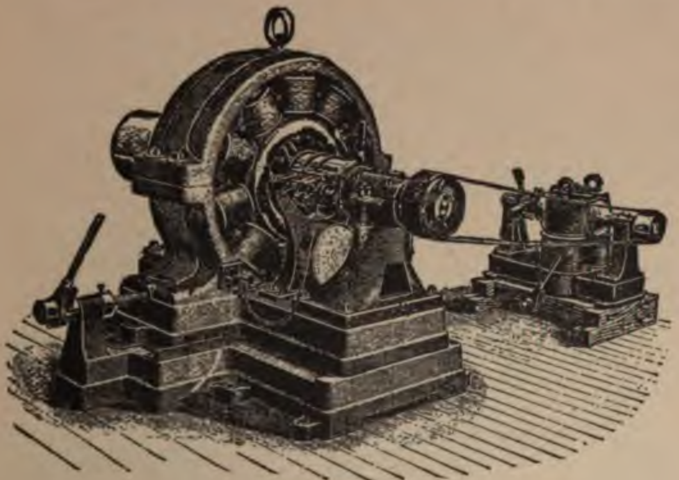


FIGURE 71.

point of use. Its adaptability for such work is apparent, because it can be generated at high voltages and transformed down to any voltage desired. It requires less copper to transmit it, due to the higher voltages employed. By the aid of transformers it can either be stepped up to a higher pressure or stepped down to as low a pressure or voltage as desired. Another great advantage is that, after it has been transmitted a considerable number of miles, by the aid of a rotary converter it can be converted into direct current.

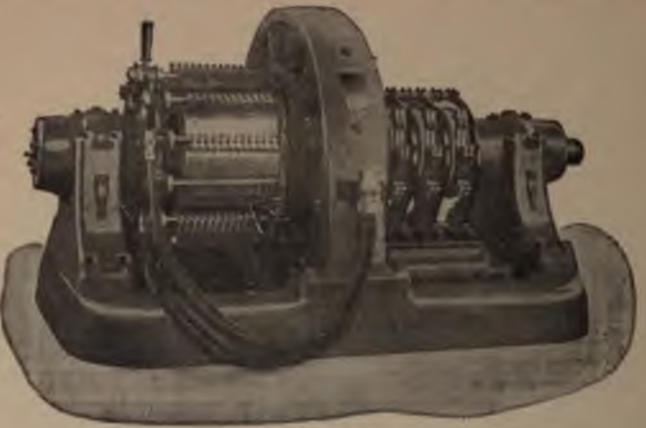


FIGURE 72.

Rotary transformers which transform the alternating current to a direct current are simply alternating current motors connected to direct current dynamos. Sometimes these machines are mounted on the same shaft; sometimes they are belted together, and in some cases the same windings are used for both machines; a commutator being mounted at one side of the armature from which direct current is taken while the alternating current is taken into the armature on a pair of collector rings on the opposite end of the shaft. In Fig. 72 is shown a view of a rotary transformer where the alternating current is taken in at the right, and direct current taken off at the commutator on the left.

By single phase we understand that the current flows out, gradually increasing in strength, then dying away and reversing in direction and again increasing and dying away. This action is shown by the curve in

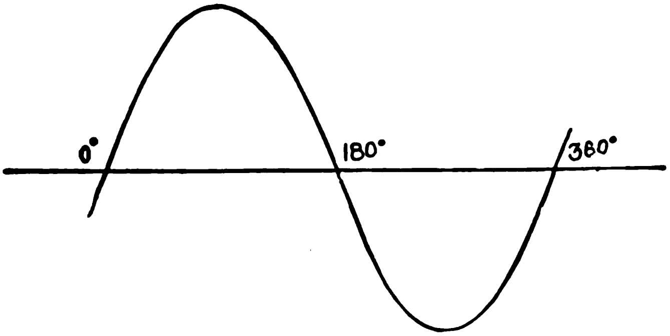


FIGURE 73.

Fig. 73. Although the single phase alternating current system is in advance of the direct current system for electrical power transmission, because permitting electrical power to be transmitted long distances at high potential, which can be readily increased or reduced by means of transformers, the single phase system is limited by the difficulty in obtaining a satisfactory self starting motor; therefore the use of the single phase current has been confined almost entirely to transmitting current for lighting. The development of the polyphase (two phase and three phase) alternating systems possess all the advantages of the single phase system and at the same time permits the use of motors having not only most of the valuable features of the continuous current motors, but also some advantages over them. In the two phase system two currents displaced 90 degrees from each other and otherwise exactly similar to the single phase currents are used. In the three phase system three currents separated 120 degrees are used. These currents are shown in Fig. 74.

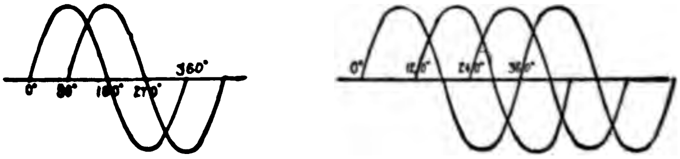


FIGURE 74.

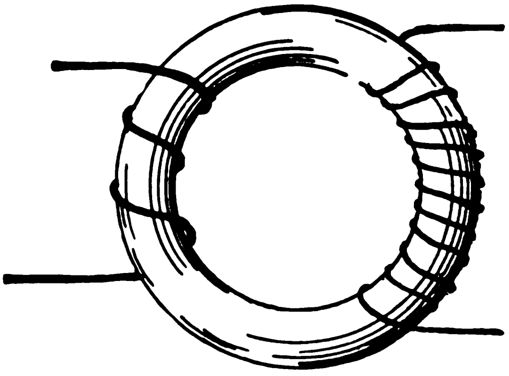


FIGURE 75.

In Fig. 75 is shown the principle upon which the transformer used in alternating current work are operated. Two separate coils of wire are wound on a ring of laminated iron. One of the coils contains a number of turns of fine wire, while the other contains only a few turns of large wire. When an alternating current is sent around the coils of fine wire, generally called the primary, a current will be induced in the coil of heavy wire, or secondary. The amount of current induced in the larger wire will be relatively greater in amperes and less in potential than that of the fine wire circuit. This ratio is almost entirely dependent upon the relative number of turns existing between the large and the small wires. To illustrate, suppose we had a current of 10 amperes at a pressure of 1,000 volts in the primary, and there were ten times as many turns of wire in the primary coil as in the secondary, then we would get a current of 100 amperes at a pressure of 100 volts in the secondary coil. This same relation would hold true whatever the ratio between the number of turns on the two coils might be. In Fig. 76 is shown a core of iron having on one end a primary coil connected to a battery. On the other end of the core is another coil connected to the

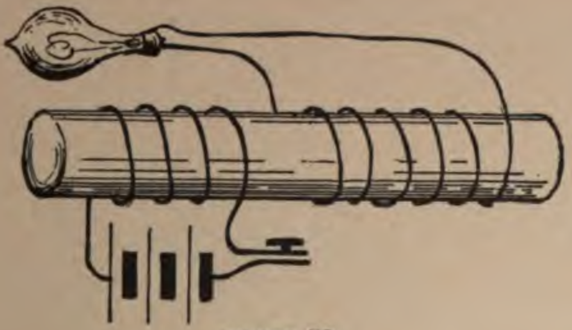


FIGURE 76.

ends of which is an incandescent lamp. By making and breaking the battery circuit the lamp may be made to flash up, due to the great voltage induced in the secondary coil. This is a good thing to remember when working with a dynamo or motor. Do not quickly break the shunt field connection, as the increased voltage due to the current induced by the field magnet when the circuit is broken is liable to puncture the insulation and necessitate the re-winding of the field coil.

CHAPTER VIII

METERS

Volt and Ampere Meters. Two of the most important instruments used in electrical work are the voltmeter and amperemeter, the latter generally called ammeter. Classed with these instruments is a meter of an important nature called the wattmeter. We will first become acquainted with the voltmeter, which is an instrument, as its name implies, for measuring the voltage or potential or electromotive force between two wires. The general construction of this instrument is shown in Fig. 77.

In this diagram we show an instrument on the order of the Weston meter. This will serve as a good illustration that the operation of meters is very similar to the operation of motors. A permanent magnet, M, causes a magnetic flux across the air gap G, and situated in this gap is a bobbin, B, on which is wound a number of convolutions or turns of copper wire. The bobbin is made to revolve on jeweled bearings. The object of the jewel bearing is to have the instrument as much devoid of mechanical friction as possible. Two springs, S, one above and one below the bobbin, carry the current to the movable part of the meter. If the current is now caused to flow around the coil of wire, it will produce a torque or twist which will move the bobbin again the two hair springs, S. Like magnetic poles repel each other and unlike magnetic poles attract each other. The current flowing around the movable bobbin produces magnetism, and the quantity or strength of magnetism so produced is proportional to the amount of current which the pressure or voltage

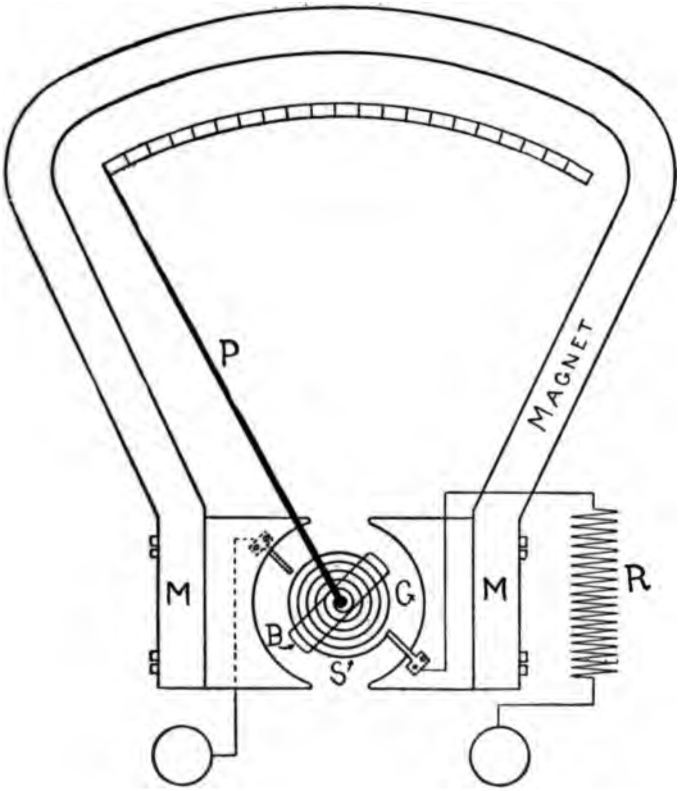


FIGURE 77.

will force through the winding of the movable bobbin so that the bobbin will continue to move until the torque exerted by the current equals the counter torque exerted by the spiral springs. A pointer, fastened to the shaft upon which the bobbin is mounted, passes over a graduated scale and indicates the pressure or volts. The capacity of this meter in volts will vary as the resistance of the wire connected in series with the bobbin varies. We will assume that we have a meter whose pointer reads from 0 to 125 volts. If we desired this same meter to read from 0 to 250 volts, we would put a resistance in the meter which would be twice as great as the one contained in the meter when reading from 0 to 125 volts. The permanent magnet of this meter is made of Tungsten steel, and this steel is artificially aged so that when the instrument leaves the factory the magnetizing power of the magnet will remain constant for a number of years. The current is brought into the instrument through the binding posts A and C, but before passing through the wire on the bobbin the current must pass over a path of very high resistance, R. This resistance is proportioned to the amount of pressure the meter is made to indicate, and in commercial construction instead of making bobbins of variable resistances, the bobbins are all made alike, and this dead resistance, R, is varied to comply with the pressure that it is to indicate with the instrument. In voltmeters used on a 500 to 600 volt circuit, this resistance will measure from 65,000 to 75,000 ohms. The current which flows through the winding on the bobbin at full voltage is very small, and when registering 110 volts amounts to about one seven-hundredth of an ampere. Since it is the number of ampere turns that produces the magnetic density in an electro magnet, it can be seen that even one seven-hundredth of an ampere, if passed around a bobbin a considerable number of times, will produce quite a strong magnetic flux and pull. Voltmeters are often referred to as being "dead beat." What is meant by dead beat is the tendency of the pointer to move from one position to another with very little or no swinging to and fro. In this type of voltmeter this dead beat effect is produced in the following manner: The core of the bobbin B being constructed of copper, when a current flows over the winding of the bobbin and causes it to revolve, eddy currents are produced in the copper (in much the same way that current is produced in the revolving armature of a dynamo), and these eddy currents tend to arrest the motion of the bobbin. In the best voltmeter construction the resistance wire used is made of a metal which will not vary much in resistance at different temperatures. It can readily be seen that, were a meter which was constructed and correctly calibrated at 70° F., surrounding temperature, mounted on switchboard in an engine-room with the temperature at 90° or 95°, the meter would not register absolutely correct, because the resistance of the wire would be considerably increased, due to the increase of the surrounding temperature. The effect of this would be a smaller flow of current at an equal voltage through the bobbin in the meter, and consequently a smaller amount of magnetism and a lower reading of the instrument.

We will assume that a copper cable of about the size of one's wrist is conducting a current of about three thousand amperes. Now, if a monkey wrench or hammer were to be lying within a few inches of this cable, before current was flowing, the monkey wrench or hammer would be attracted to the cable. The rapidity with which the monkey wrench would be attracted to the cable would be proportional to the weight of the iron in the wrench and the amount of the current flowing through the cable. This, I think, will explain an electrical phenomenon which will assist us to understand what are called the magnetic vane voltmeters and ammeters. This principle is shown in Fig. 78.

A certain amount of current passing over the path A, which consists of several turns of wire, will attract an iron form, B, mounted on the spindle with the

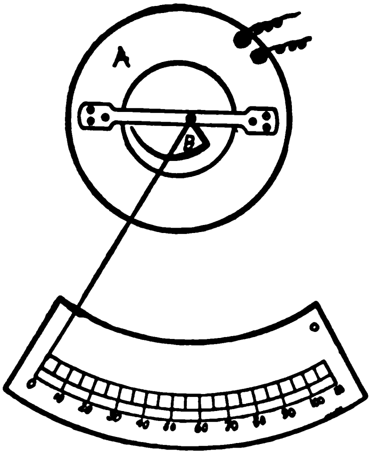


FIGURE 78.

pointer. The attraction will be proportional to the amount of current flowing over the copper conductor. The advantage of such an instrument is its simplicity, but the disadvantage is its inaccuracy. Its simplicity is apparent, and its inaccuracy is due to the residual magnetism that remains in the iron part B when the current through the conductor has been reduced. When the indicator is caused to move upward on the scale, the instrument will register practically correct, but as the flow of current over the conductor A diminishes or decreases, the residual magnetism remaining in the iron part B will have a tendency to cause it to lag back. Amperemeters are constructed on practically the same lines as explained in the construction of voltmeters, except that in ammeters the whole current to be measured passes through the coil A, this coil being made of comparatively few turns of large wire, while in voltmeters the resistance is very high. Ammeters are placed in series with one of the leads and voltmeters in shunt with the current to be measured. In some ammeters a resistance block, usually called a shunt, is employed, over which the main current is caused to flow, and the ammeter is connected to both ends of this resistance block. In this way only a very small portion of the total current is caused to flow through the ammeter. In this case a milli-voltmeter, with the scale graduated to amperes, is employed. By Ohm's law we know that the voltage is equal to the current times the resistance, $E = CR$. The resistance remaining constant, the voltage is proportional to the current, so that the amount of current sent through the milli-voltmeter or ammeter is exactly proportional to the current flowing through the shunt. Fig. 79 shows connections for ammeters which carry the entire current and those used with a shunt.

The object of such a construction is apparent. In the installation of the switchboard, where each ammeter registers several thousand amperes, it is not necessary to construct the large conductors in such a manner that the total current is caused to flow through the ammeter. For each 1,000 amperes passing over the shunt only about one-half an ampere will pass through the ammeter, and the little bobbin will then cause a deflection of the pointer in the meter and the pointer will register 1,000 amperes. Meters of this description are usually connected to their resistance blocks by a pair of No. 16 flexible lamp cords. When installing meters of this class, never cut off any of the flexible cord which is supplied with the ammeter, as the resistance of the cord becomes a part of the resistance in the meter. By cutting off some of this cord it can be readily seen that the meter will register more current than it should.

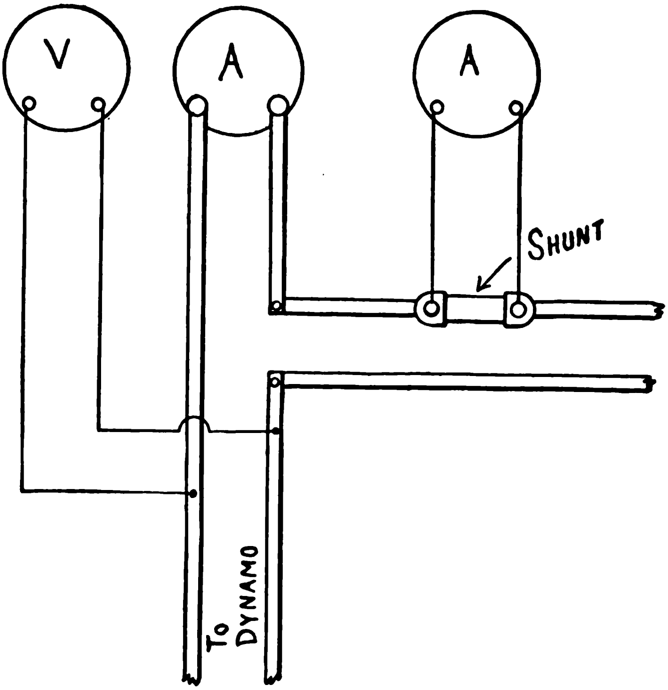


FIGURE 79.

Another kind of meter is constructed on the solenoid principle, and is shown in Fig. 80. In this instrument the helix is a bare copper wire and is wound in an open coil form. It is curved in the shape of a segment of a circle, the center of which is at the pivot on which the needle is suspended. The pointer or needle is attached and projects downward to the scale. The helix is made of copper rod or is cast to the shape required. Being of an open coil type, it is not necessary that it be insulated with insulating material because the air spaces between the turns becomes the insulation. Although not the best insulator by any means, there are few substances which possess better insulating qualities than air, although on account of its absorption of moisture, it becomes often a much poorer insulator than many other materials. In this type of

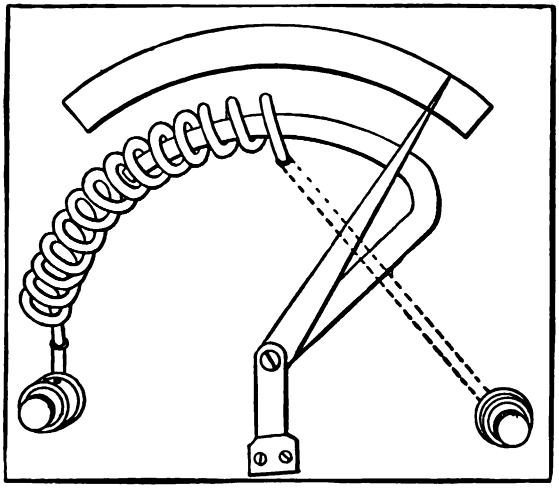


FIGURE 80.

instrument it will be seen that as the number of amperes flowing over the coil is increased it produces an increased electromagnetic pull on the iron section or core entering it. As this electro magnetic pull is

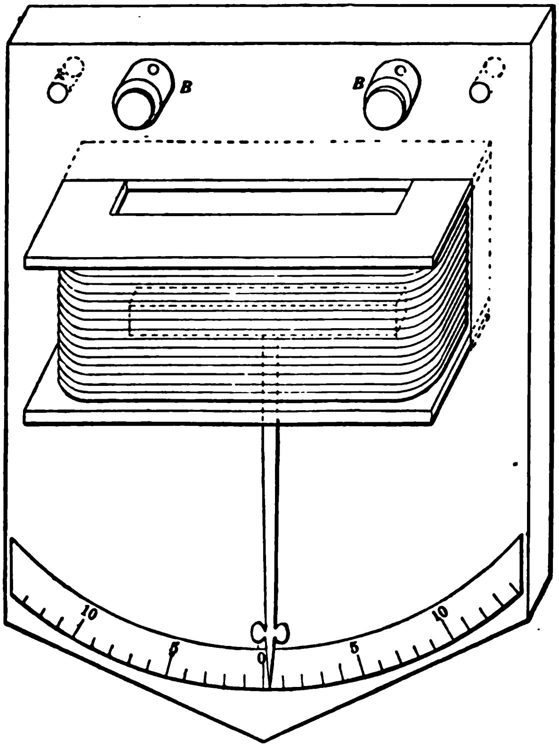


FIGURE 81.

increased, the core moves up into the helix and causes a deflection of the pointer across the scale on the instrument. This type of instrument has the same objection as that of the magnetic vane instrument, namely, residual magnetism of the iron, and hence error in the reading while the current flowing is being diminished.

Another style of simple ammeter or voltmeter is shown in Fig. 81. This instrument consists of a frame made of non-magnetic material, around which the wire is wound, the ends of the wires being connected to the binding posts. The armature of this instrument, as in all other similar instruments, is connected to the pointer, and may be constructed of several pieces of iron. The principle of its working is similar to that described above, in that the armature tends to set itself at right angles to the wire through which the current passes. This style of instrument is used where current is liable to flow in either direction.

A simple form of meter for measuring current is shown in Fig. 82. Here we have an amperemeter which consists of a strip of copper fastened to a block of wood or other insulating material, as shown at A. A piece of magnetized steel, B, to which a needle, C, is attached, swings on a pivot or shaft which is suspended at the bridge D. A scale is provided from which the number of amperes flowing can be obtained. The needle is rigidly attached to the magnetized steel B and moves with it. The action of this instrument is as follows: When a magnetized piece of steel is brought near to a conductor through which a current of electricity is passing, the magnetized steel tends to set itself at right angles to the direction of the current. The stronger the current becomes, or the more highly magnetized the piece of steel may be, the nearer to a position of right angles the armature will assume. It is not practical to use this construction of an instrument to cover a range of more than one-half of a right angle, for when the needle moves through an angle of about 50 degrees, it will require a much greater increase of current in proportion to the movement to obtain the deflection and the additional degree of the indicating needle. Such an instrument as the above may also be used to determine the direction of flow of current in a wire and is sometimes quite convenient on arc circuits which are liable to have their currents reversed either by wrong plugging of the board or the reversing of polarity in the dynamo.

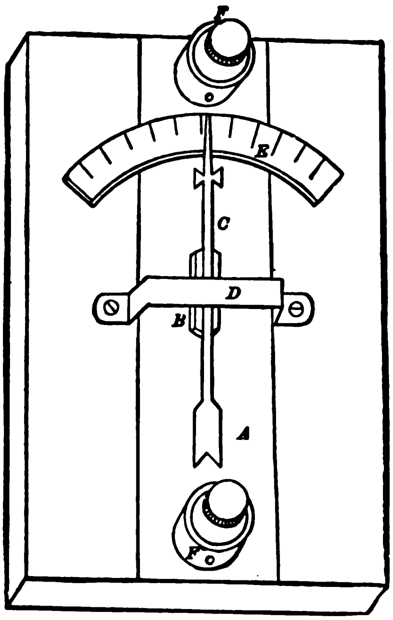


FIGURE 82.

Voltmeters and ammeters used with alternating currents must, of course, differ in some respects from [illegible] mag- [illegible]

[illegible] instruments [illegible] range.

[illegible] [illegible] was [illegible] any other place where it was desirable to measure the power furnished in the form of electricity, there were several kinds of differently constructed meters used to measure the amount of current. Some of these meters were based on the chemical action of the current; the current in passing to the work depositing metal from one plate to another. The plates or terminals of the meters were weighed before being placed in the circuit and again weighed on being taken out, the amount of metal having been deposited determining the amount of current used, as explained in the fore part of the book. Of late, however, most of the recording wattmeters in use are operated on the principle of the Thomson wattmeter. As has been explained under the definition of units, the work done (watts) is equal to the current (amperes) multiplied by the electromotive force (volts), or $W = C \times E$. For a wattmeter to register correctly it must take a record of the volts and amperes.

The Thomson wattmeter is simply a small motor in which the armature is used as a voltmeter and the fields as an ammeter. The armature is wound with fine wire and is connected to a small commutator made up of metal bars. Two very thin metal brushes bear on this commutator and carry the current to and from the armature. The armature is connected across the mains in just the same way as a voltmeter would be connected. The fields are wound with a coarse wire and are connected in series with the main circuit, thus acting as an ammeter. It can readily be seen that with the armature influenced only by the voltage, and the fields by the current passing through the mains, the two acting together will correctly measure the power supplied. As the voltage rises or lowers, the speed of the armature will be affected accordingly, and as the current through the fields varies the electromagnetic effect produced by the fields and in which the armature revolves will vary, thus also varying the speed. By reference to Fig. 83, the fields F F are connected in series with one of the mains and the armature A is

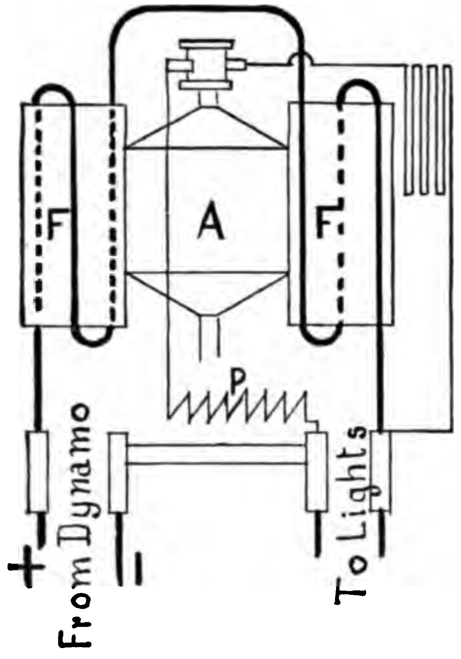


FIGURE 83.

connected across the mains. Fig. 84 is a simplified diagram. Attached to the shaft on which the armature rotates is a copper disc which revolves between the poles of a permanently magnetized steel magnet. Eddy currents are generated in this copper disc as the armature rotates, thereby acting as a brake against which the armature must work. Connected to the top of the shaft is a train work of wheels which move small pointers over the dials on the face of the instrument and record the amount of current which has passed through the meter. As no iron is used in either the armature or fields of the motor, the meter can be used on either alternating or direct current.

In Fig. 85 we show a two wire meter with the case removed.

In Fix. 86 a three wire meter is shown.

Directions for Reading Meter Dials. To correctly read the sum indicated on the dial of a recording meter, the directions given herewith should be thoroughly understood and carefully followed.

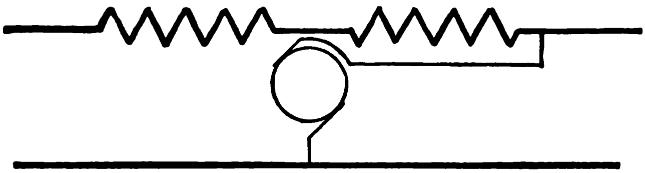


FIGURE 84.

The figures (1,000, 10,000, etc.) under or over each dial refer to a complete revolution of the hand at that dial.

Therefore, each division on the dial to the extreme right indicates not one, two, three, or four thousands of units, but one, two, three, or four hundreds of units.

A complete revolution of the hand counts one thousand, and will have moved the hand on the second dial one division. Thus in reading Diagram No. 6, Fig. 87 the first dial (that on the extreme right) indicates 700, not 7,000.

A hand to be read as having completed a division, must be confirmed by the dial before it (to the right). It has not completed the division on which it may appear to rest, unless the hand before it has reached

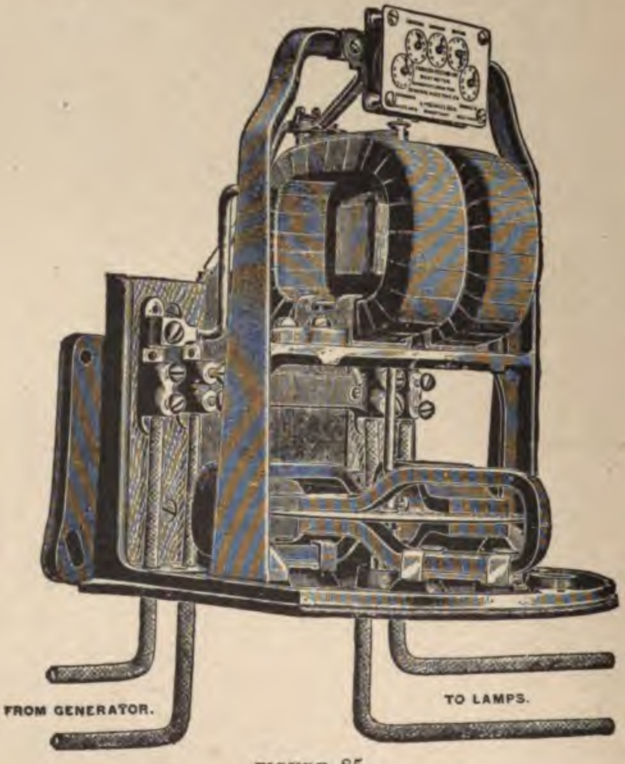


FIGURE 85.

or passed 0, or, in other words completed a revolution. For this reason it will be found easier and quicker to read a dial from right to left, as shown by reading Diagram No, 2, Fig. 87.

The first dial (the extreme right) indicates 900. The second hand apparently rests on 0, but since the first rests only on 9 and has not completed its revolution,

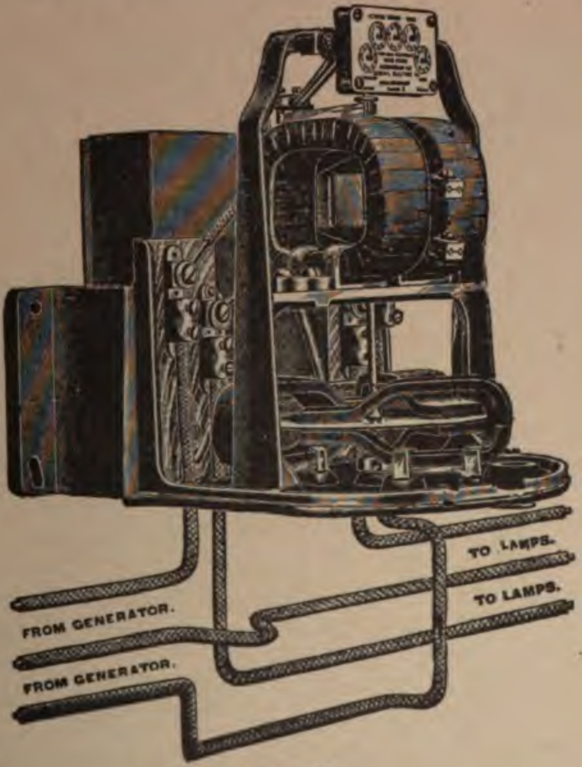


FIGURE 86.

the second dial also indicates 9. This 9, placed before the 900 already obtained, gives 9,900.

This is also true of dial 3. The second hand, at 9, has not quite completed its revolution, so the third has not completed its division, therefore another 9 is obtained, making 99,900. The same is true of dial 4, making 999,900.

The last dial (the extreme left) appears to rest on 1, but since the fourth is only 9, the last has not completed its division, and therefore reads 0. The total reading is 999,900.

The hands are sometimes slightly misplaced. In Diagram No. 8 the first diagram (the extreme right) reads 0, which gives 000. The hand of the second dial is misplaced. As the first registers 0, the second should rest exactly on a division; therefore it should have reached 8, making 8,000. The third hand is apparently on 3, but since the second hand is at 8, the third cannot have completed a division and must, therefore, indicate 2. The two remaining dials are correct, and make a total of 9,928,000.

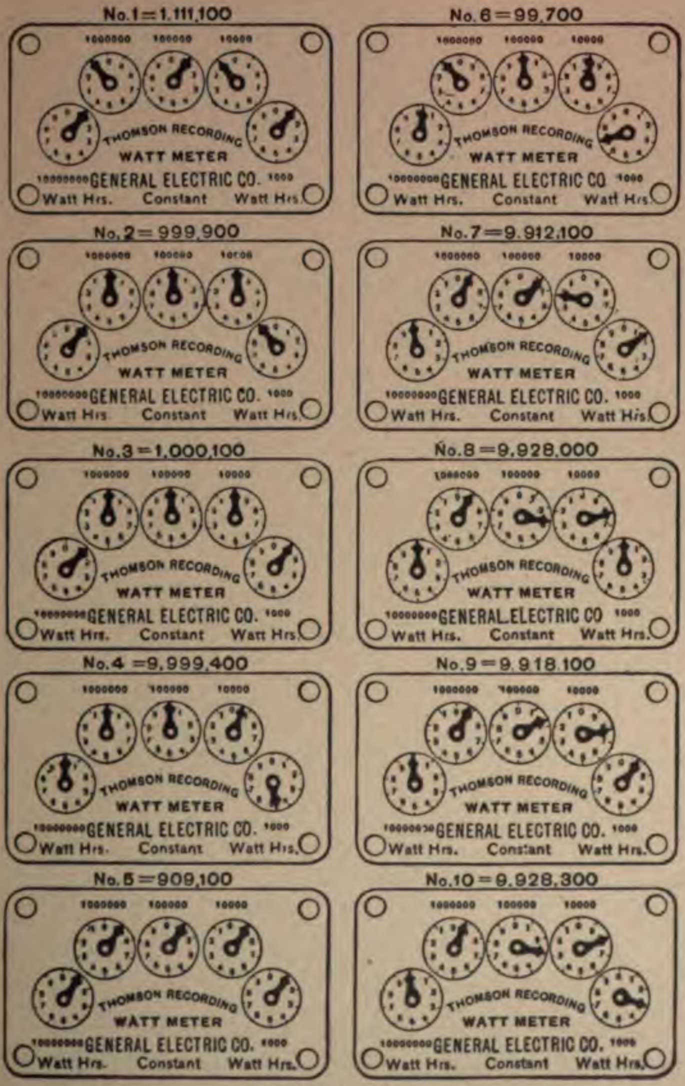
In Diagram No. 9, the second dial hand is misplaced, for since the first indicates 1, the second should have just passed a division. As it is nearest to 8 it must have just passed that figure. The remaining three dials are approximately correct. The total indication is 9,918,100.

In Diagram No. 10, the second and fourth dial hands are slightly behind their correct position, but not enough to mislead in reading. The total indication is 9,928,300.

By carefully following these directions little difficulty will be found in reading the dial, even when the hands become misplaced.

Note whether there is a constant marked on the dial. If there is, multiply the dial reading by the constant. With constant ½, multiply by ½; that is, divide by 2.

The "constant" of a meter is the term applied when



No. 1 = 1.111,100

No. 2 = 999,900

No. 3 = 1,000,100

No. 4 = 9,999,400

No. 5 = 909,100

No. 6 = 99,700

No. 7 = 9.912,100

No. 8 = 9,928,000

No. 9 = 9.918.100

No. 10 = 9,928,300

FIGURE 87.

the meter is constructed to run at a lower speed than what would be necessary to measure the true number of watts which has passed through it. For instance, if the constant is 2 and the meter has registered 5,000 watt-hours, then the meter having run only half as fast as it should, we multiply 5,000 by 2, which gives us 10,000 watts as the actual amount that has passed through the meter. This scheme becomes necessary in order to register a large amount of current with a meter small in bulk or size. For convenience the maker often takes a 220 voltmeter which would read the number of watts direct on the dial at 220 volts and sells it for a 110 voltmeter by marking a constant on the dial of the meter.

CHAPTER IX

Arc Lamps. The principle on which the arc lamp operates is shown in Fig. 89. Current is caused to flow from one carbon point to another through a space or gap between the carbons. The heat of the arc is sufficiently high to disintegrate the carbon and reduce it to a vapor, this vapor filling the space between the carbon points. The current passes over this space in a bow-shape path or arc, and it is from this fact that the lamp gets its name. The arc is constantly moving, and generally revolves around the carbon points. This can be easily seen by looking closely at a burning lamp through a smoked glass. After a lamp has been burning for some time on direct current the carbons assume the shape shown in Fig. 88, the upper or positive carbon assuming a cup shape, while the lower carbon generally burns to a point. This cup shape formation on the upper or positive carbon acts as a reflector to throw the light downward. The positive carbon burns away about twice as fast as the negative carbon and lamps must be trimmed accordingly. Sometimes the current feeding arc lamps (on direct current systems) becomes reversed, either through the dynamo reversing its polarity or through wrong plugging of the switchboard. The lamps will now burn "upside down," or, in other words, the bottom carbon will be the positive one. In such a case, if let go, the carbon holders of the lamp will be burned and the lamp will burn for only half the time for which it was intended, owing to the fact that the lower or negative carbon is only one-half as long as the upper or positive carbon. Such a condition can be determined by either of the following ways: See if the light is being thrown downwards. See which carbon is burning away the faster. Raise the carbons and notice the formation of the carbon tips. When the carbons are separated it will be noticed that the tip of one carbon is considerably hotter than the other and is heated a longer distance from the point; this is the positive carbon.

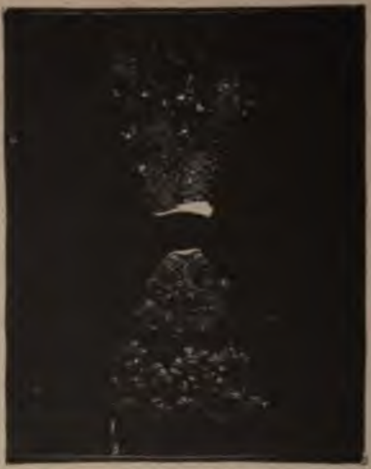


FIGURE 88.

The action of the arc lamp used on direct current constant current systems is shown in Fig. 89. Current passes through wire T and over the coarsely wound solenoid M, thence down to the carbon, across the arc or crater, into the negative carbon and out again on the wire T′. The regulating action is as follows: A coil M′, constructed of fine wire and of high resistance, is connected in shunt across the arc. The action of the current flowing through the solenoid M across the crater or arc produces a magnetic pull on the solenoid core A and causes a separation of the carbons. As these carbons burn away the resistance across the crater increases and a very small portion of the main current is caused to flow through the shunt coil M′. The magnetic pull of the shunt solenoid overcomes that of the series solenoid with the result that the solenoid core A is drawn into coil M′ and the upper carbon thus lowered, decreasing the gap at the arc. In this way a constant regulation is going on, tending to keep the two carbons at a uniform distance apart. The upper carbon rod is held by means of a clutch. When the carbons have burned away, so that the lowering of the solenoid does not lower them to the proper extent, the clutch is released and the carbon drops, thus feeding the lamp. Some lamps are manufactured wherein the lower carbon is positive. This causes the light emitted from the crater to be projected upwards. The arc lamp frame is supplied with a shade on which the light cast from the arc is reflected downward. The advantage of this system is to obtain a better diffusion and distribution of the light beneath the arc lamp. This lamp is not now generally used.

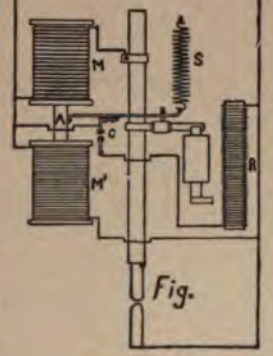


FIGURE 89.

Fig. 90 shows a diagram of connections for the improved Brush arc lamp. These lamps are used on constant current or series systems and their action is as follows:

The carbons should rest in contact when the lamp is cut out. When the switch is opened, part of the current from the positive terminal hook P goes through the adjuster to the yoke and thence through the carbon

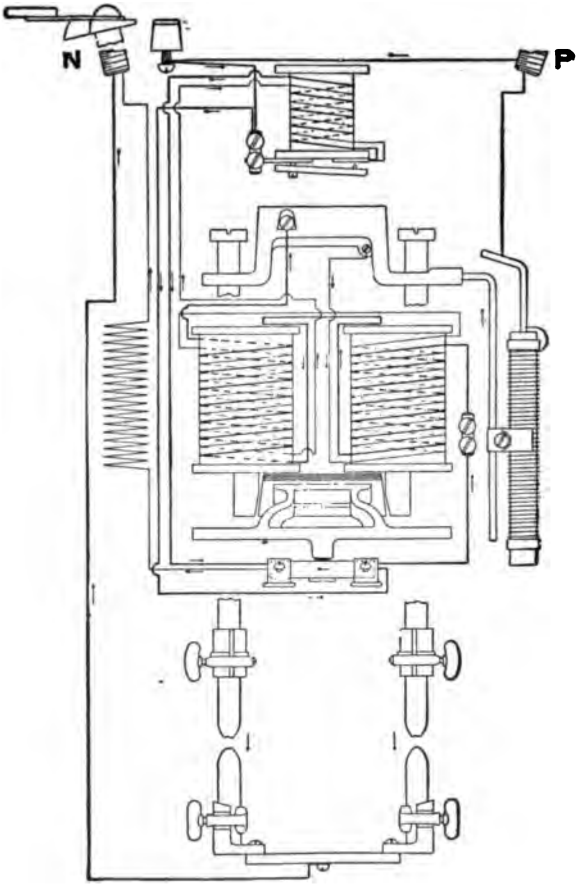


FIGURE 90.

rod and carbons to the negative terminal hook N. The remainder of the current goes to the cutout block, but, as the cutout block is closed at first, the current crosses over through the cutout bar to the starting resistance, and so to the negative side of the lamp. A part of it, however, is shunted at the cutout block through the coarse wire of the magnets and so to the upper carbon rod and carbons and out. This shunted current energizes the magnet and so raises the armature which opens the cutout and at the same time establishes the arc by separating the carbons.

The fine wire winding is connected in the opposite direction from the coarse wire winding, and its attraction is therefore opposite. When the arc increases in length, its resistance increases, and consequently the current in the fine wire is increased. The attraction of the coarse wire winding is therefore partly overcome and the armature begins to fall. As it falls, the arc is shortened and the current in the fine wire decreases. The mechanism feeds the carbons and regulates the arc so gradually that a perfect, steady arc is maintained.

The fine wire of the magnets is connected in series with the winding of a small auxiliary cutout magnet at the top of the mechanism.

This magnet, which also has a supplementary coarse winding, does not raise its armature unless the voltage at the arc increases to 70 volts. The two windings connect at the inside terminal on the lower side of auxiliary cutout magnet, and the current from the fine wire of the main magnets passes through both windings and then to the cutout block and so to the starting resistance and out.

If the main current through the carbon is interrupted (as by breaking of the carbons) the whole current of the lamp passes through the fine wire circuit. Before this excessive current has time to overheat the fine wire circuit, it energizes the auxiliary cutout magnet, and closes a circuit directly across the lamp through the coarse wire on the auxiliary cutout to the main cutout block, and thence to the negative terminal.

The auxiliary cutout operates instantly, and prevents any danger to the magnets during the short period required for the main armature to drop and throw in the main cutout. When the main cutout operates, the armature of the auxiliary cutout falls, because there is not sufficient current in that circuit to energize the magnet.

The voltage at which the auxiliary cutout magnet operates depends on the position of its armature, which is regulated by the screw securing the armature in position. It should not be adjusted to operate at less than 70 volts.

One of the three methods of suspension may be used for Brush lamps. If chimney suspension, which is the most common, is adopted, the wire, cable or rope used to suspend the lamp must be carefully insulated from the chimney. For this purpose a porcelain insulator should be inserted between the support and the lamp, as shown in Fig. 91.

Hook suspension may be used to advantage in some places, but great care must be taken to insulate the supporting wires from any conductors, as the hooks form the terminals of the lamps.

The most convenient arrangement for indoor use is to suspend the lamp from a hanger board. The porceiain base of the hanger board prevents short circuits or grounds.

A protecting hood is not necessary for outdoor use, as the lamp chimney and its base are one casting and effectually exclude rain or snow water.

The lamps run on circuits of 6.6 amperes for 1,200 and 9.6 amperes for 2,000 nominal candlepower. In case it is necessary to run a lamp on a circuit differing from the standard, the lamp may be adjusted by moving the contact on the adjuster. About one ampere either above or below the normal may be compensated for by this means.

Permanent adjustment for special circuits of variation greater than one ampere is made by filing the soft iron armature. The clutch should be so adjusted that the center of the armature is $\frac{13}{16}$ in. above the plate when the trip on the first rod is touching the bushing, and $\frac{11}{16}$ in. when the trip on the second rod is in a similar position. A small gauge is convenient for adjusting the clutch. The position of the trip of the clutch determines the feeding point of the lamp.

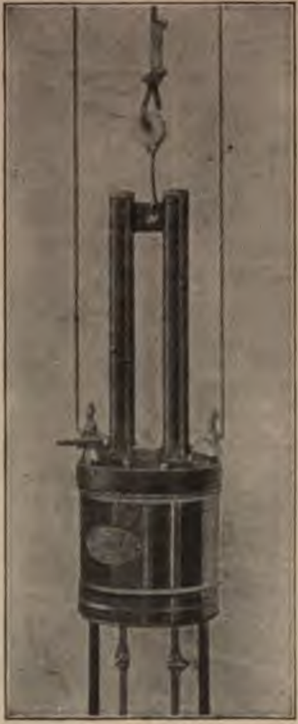


FIGURE 91.

After thoroughly repairing and cleaning the lamp, it should be run a short time before installing. Lamps should not be tested in an exposed place, as a strong draft of air will cause unpleasant hissing which may be mistaken for some internal trouble.

Lamps should not hiss or flame if good carbons are used. A voltmeter should always be used when adjusting or testing.

The lamp terminals are marked P (positive) and N (negative) and should be connected into circuit accordingly.

The carbons should be solid and of uniform quality. For the best results, the upper carbon should be 12 in. × $\frac{7}{16}$ in., and the lower 7 in. × $\frac{7}{16}$ in. The stub of the upper carbon may then be used in the lower holder when retrimming.

At each trimming the rod should be carefully wiped with clean cotton waste. If any sticky or dirty spots appear, which cannot be readily removed with waste, use a piece of well-worn crocus cloth, always being careful to use a piece of clean waste before pushing the rod into the lamp. It should never be pushed up into the lamp in a dirty condition.

The carbon rod may be unscrewed and removed by a small screw driver or small strip of metal inserted in the slot cut in the rod cap. The cap will remain in the hole through the yoke when the rod is taken out.

In Fig. 92 an interior view of the Thomson-Houston arc lamp is shown. This lamp is also used on constant current systems.

The lamps should be hung from the hanger boards provided with each lamp, or from suitable supports of wire or chain.

As the hooks on the lamp form also its terminals, they should be insulated, where a hanger board is not used, from the chains or wires used to support the lamp.

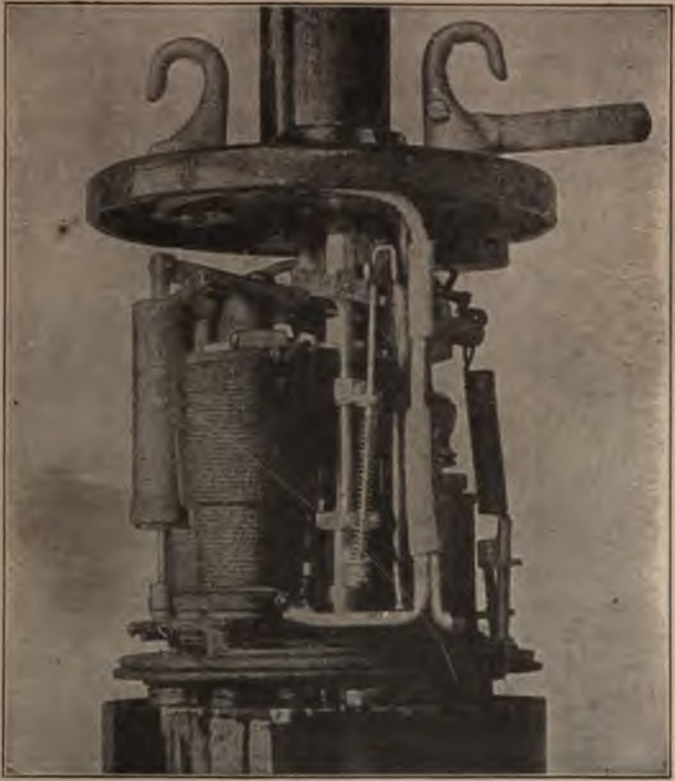


FIGURE 92.

When the lamps are hung where they are exposed to the weather, they should be covered with a metal hood, to prevent injury from rain and snow.

In such cases, care should be taken that the circuit wires do not form a contact on the metal hood and short circuit the lamp.

Before the lamps are hung up they should be carefully examined to see that the joints are free to move, and that all connections are perfect.

No lamp should be allowed to remain in circuit, with the covers removed and the mechanism exposed. Such practice is dangerous, and in violation of insurance rules.

The object of testing the lamps in the station is to find any defects, if such exist, and to test all the conditions of running before delivering them to customers. The lamps should not be hung up in their respective places in the external circuit, until everything is running with perfect satisfaction.

The tension of the clamp which holds the rod is adjusted by raising or lowering the arm at the top of the guide rod. (See Fig. 93.) If the tension is too great the rod and clutch will wear badly and the feeding will be uneven, causing unsteadiness in the lights. Too little tension will not allow the clutch to hold up the rod and any sudden jar to the lamp will cause the rod to fall and the light to go out.

The double carbon, or M lamp, should have the tension of the second carbon a trifle lighter than the first one.

When adjusting the tension, be sure to keep the guide rod perpendicular and in perfect line with the carbon rod; it should be free to move up and down without sticking.

The tension of the clutch in the D lamp should be the same as that of the K lamp. It is adjusted by tightening or loosening the small coil spring from the arm of the clutch to the bottom of the clamp stop.

To adjust the feeding point in the K lamp, press down the main armature as far as it will go, then push up the rod about one-half its length, let go the armature and then press it down slowly and note the distance of the bottom side of the armature above the base of the curved part of the pole. When the rod

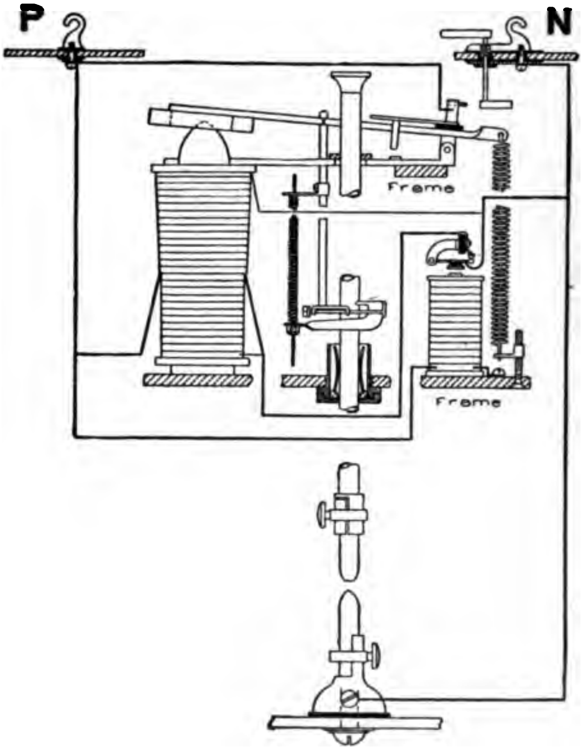


FIGURE 93.

just feeds, this distance should be ¼ in. If it is not, raise or lower the small stop which slides on the guide rod passing through the arm of the clutch, until the carbon rod will feed when the armature is ¼ in. from the rocker frame at base of pole.

To adjust the feeding point of the M lamp, adjust the first rod as in the K lamp. Then let the first rod down until the cap at the top rests on the transfer lever. The second rod should feed with the armature at a point 1/16 in. higher than it was while feeding the first rod, that is, it should be 5/16 in. from rocker frame at base of pole.

The feeding point of the D lamp is adjusted by sliding the clamp stop up or down, so that the rod will feed when the relative distances of the armature of the lifting magnet and the armature of the shunt magnet from rocker arm frame are in the ratio of 1 to 2. There should be a slight lateral play in the rocker, between the lugs of the rocker frame.

The armatures of all the magnets should be central with cores, and come down squarely and evenly. There should be a separation of 1/32 in. between the silver contact points, when the armature of the starting magnet is down. This contact should be perfect when the armature is up. The arm for adjusting the tension should not touch the wire or frame of the lamp when at the highest point. There should be a space of 3/32 in. or ⅛ in. between the body of the clutch and the arm of the clutch, to allow for wear on the bearing surfaces.

Always trim the lamp with carbons of proper length to cut out automatically, that is, have twice as much carbon projecting from the top as from the bottom holder. Always allow a space of ¼ in., when the lamp is trimmed, from the round head screw in the rod, near the carbon holder, to the edge of the upper bushing, so that there will be sufficient space to start the arc.

The arcs of the 1,200 candlepower lamps should be adjusted to $\frac{3}{64}$ in., with full length of carbon. Arcs of 2,000 candlepower lamps should be adjusted from $\frac{1}{16}$ to $\frac{3}{32}$ in. when good carbons are used.

The action of a lamp that feeds badly may often be confounded with a badly flaming carbon. The distinction can readily be made after a short observation. The arc of a lamp that feeds badly will gradually grow long until it flames, the clutch will let go suddenly, the upper carbon will fall until it touches the lower carbon, and then pick up. A bad carbon may burn nicely and feed evenly until a bad spot in the carbon is reached, when the arc will suddenly become long and flame and smoke, due to impurities in the carbon. Instead of dropping, as in the former case, the upper carbon will feed to its correct position without touching the lower carbon.

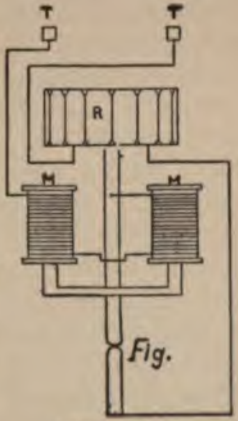


FIGURE 94.

In a series arc lamp the shunt coil is used to regulate the voltage over the arc. With constant potential arc lamps this shunt coil is not needed, owing to the fact that the voltage over the lamp is practically constant. Fig. 94 shows a diagram of an arc lamp for use on constant potential circuits. The upper carbon is supported by means of an iron yoke which forms a core to the two solenoids M M. Current entering binding post T passes through the windings of these two solenoids and then through the carbons and through the resistance coil R to the other terminal of the lamp. The action of the lamp is as follows: Current passing over the solenoids M M is regulated by the resistance across the arc. This current produces an electromagnetic pull on the iron core and floats, magnetically, the core and upper carbon. When the carbons burn away at the crater the distance from point to point of the carbons is increased and a corresponding increase in resistance to the flow of the current takes place. This reduces the flow of current around the solenoids and correspondingly reduces the electromagnetic pull on the core; the iron core and carbon fall a slight distance by gravity. In so doing the distance at the crater is decreased and the flow of current increased, thus increasing the flow of current around the solenoids and drawing up the core and carbons. In this way a very nice equilibrium between gravity and magnetic pull is maintained. It will be noticed that this lamp has no automatic cutout as has the constant current arc lamp. In a series arc lamp when the carbons are all consumed, the automatic cutout closes the circuit from the positive and negative binding posts of the individual arc lamp, thereby maintaining a path through the arc lamp over which the current can continue to flow to supply the remaining arc lamps in the series circuit.

The series arc, as its name would indicate, is the most simple of all lighting circuits. The lamps are arranged so that all the current from the positive pole of the dynamo goes through each, and from the last on the conductor leads back to the dynamo. The series system is more generally used where it is desired to illuminate a large district, as in street lighting. It is also used to some extent in store lighting, although the series arc is fast being replaced with the constant potential arc for this purpose.

In the low tension or constant potential arc lamp the use of a cutout mechanism is not necessary, because these lamps burn singly across the system of wiring, where a constant potential is maintained, and hence when the carbons are all consumed, current simply ceases to flow across them. In the open arc lamp the potential across the crater is usually from 45 to 50 volts, while in the inclosed arc lamp the potential across the crater is from 68 to 75 volts. This is due to the increased resistance through the crater, because of the peculiar nature of the gases emitted from the crater burning in a condition with practically no atmosphere. When such an arc lamp is connected across a 110 volt circuit, the lamp contains a resistance coil in the mechanism box over which the current must flow before producing the arc, R (Fig. 94). This resistance coil assists to reduce the pressure from 110 volts down to the pressure required by the arc or crater. If, for instance, the electromotive force across the wires supplying current to a low tension arc lamp is 110 volts and the pressure required to maintain the arc or crater is 70 volts, then the resistance coil chokes down the electromotive force from 110 to 70, or 40 volts. If the arc consumes 4 amperes of current then the loss is 4 (amperes) times 40 (volts), or 160 watts. This 160 watts is lost by heat radiating to the atmosphere from the wire of the resistance coil. The constant potential lamp is usually referred to as the low tension arc lamp. The high tension arc lamp generally burns with the arc in the open air, while the low tension lamp burns with the arc encased in a small glass bulb so arranged as to permit the upper carbon to slide into the bulb in a manner that will maintain, as near as possible, a condition whereby the arc burns in a gas containing no oxygen. The enclosed arc lamp has the advantage of burning a considerable number of hours without being recarboned or trimmed; but it also has the disadvantage that the bulb enclosing the arc turns black after burning for some time, caused by the gases emitted from the arc. This renders the bulb partially opaque, consequently imprisoning a considerable quantity of useful light. Enclosed arc lamps are also operated in series systems, and where they are so used the objection of loss due to the cutting down of the voltage (as in constant potential lamps) is overcome. Enclosed lamps are also operated on alternating current systems.

The operation of the alternating arc lamp and the mechanism in the lamp is very similar to that of the direct current arc lamp, but the magnets instead of being constructed of solid iron, are laminated in a similar manner as the system of lamination explained in the construction of armatures. These laminated cores and other parts forming the magnetic circuit in the arc lamp are necessary to avoid eddy currents. The crater has neither a cup shape on the upper carbon nor a point on the lower carbon, because current flows through the crater alternately positive and negative with each alternation. In the alternating arc lamp the upper and lower carbons burn away with almost equal rapidity, and the same quantity of light is projected upward as downward.

In Fig. 95 is shown an arc lamp with case removed. The two upper coils are the coarsely wound series coils, while the two lower coils are the finely wound shunt coils. This lamp is adapted for an enclosed arc bulb. The magnetically attracted cores are U shaped, and both cores are connected together mechanically by non-magnetic metal, such as brass or zinc, so that the magnetism set up in the shunt coils will not be affected by the magnetism set up by the series coils. This scheme is used in alternating current lamps, while in direct current lamps the cores are made of H shaped iron not laminated.

In Figs. 96 to 98 are shown three views of series enclosed alternating current arc lamps of the Western Electric Company.

Fig. 96. Side view of lamp, showing one series and one shunt spool, lever movement and adjusting weight. This weight is fastened upon a threaded rod, and the finest adjustment can be obtained by screwing the weight backward or forward. Threads can be clamped in position when the correct adjustment is obtained.

Fig. 97. Front view of lamp, showing shunt spools, supporting resist ance and cutout. Note that lever carries no current when in normal working position, but that insulated bridge forms connection across two contacts, completing cutout circuit when in position shown in cut.

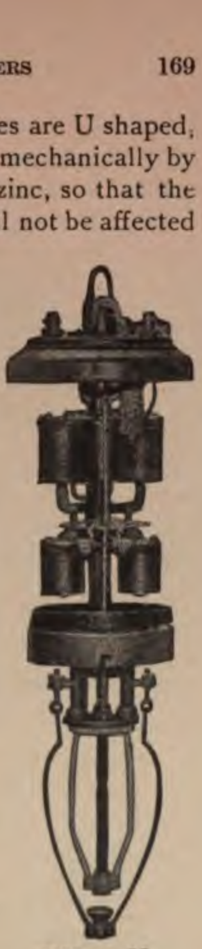


FIGURE 95

Fig. 98. Rear view of lamp, showing series spool, short circuiting switch and manner of suspending dash pot. Note that the dash pot is inverted, allowing sucn

dirt as may accumulate therein to fall out rather than in the dash pot.

The three cuts show the manner of suspending the spools and their accessibility, it being possible to remove any spool by simply taking out the two screws which fasten it to the frame, and lifting it off the lower support.

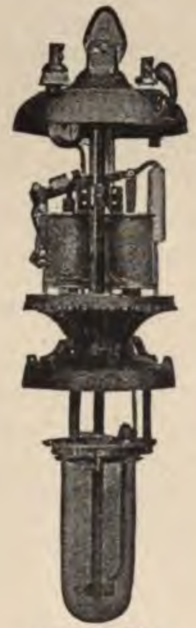


FIGURE 96.

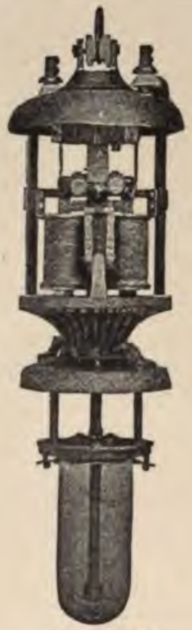


FIGURE 97.

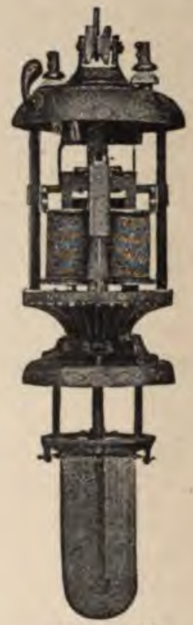


FIGURE 98.

The carbons used in arc lamps are extremely hard and dense. They are made from a mixture of powdered gas house coke, ground very fine, and a liquid like molasses, coal tar, or some similar hydro-carbon, forming a stiff, homogeneous paste. This is molded into rods or pencils of required size and length, or other shapes, being solidified under powerful hydrostatic pressure. The carbons are now allowed to dry, after which they are placed in crucibles or ovens, thoroughly covered with powdered carbon, either lampblack or plumbago, and baked for several hours at a high temperature. After cooling, they are sometimes repeatedly treated to a soaking bath of some fluid hydro-carbon, alternated with baking, until the product is dense as possible, all pores and openings having been filled solid. Arc carbons are often plated with copper by electrolysis, to insure better conductivity.

It is said that one 2,000 candlepower arc lamp will light in open yards 20,000 sq. ft.; in railroad stations, 14,000 sq. ft.; in foundries and machine shops, 5 000 to 2,000 sq. ft. Where good, even illumination is desired, it is advisable to use a greater number of smaller lamps evenly distributed.

CHAPTER X

Incandescent Lamps. As nearly every one is familiar with the construction of the incandescent lamp no detailed description will be undertaken, suffice it to say that the incandescent lamp comprises a carbon filament enclosed in a glass bulb from which the air has, as far as possible, been withdrawn, the carbon filament being soldered to the ends of small platinum wires entering the glass shell. Incandescent lamps can be burned either in series or in multiple; the multiple system being the most used. Series incandescent lamps are used to a considerable extent in the smaller towns for street lighting and also for the small miniature lamps burned in series on a constant potential system and used for decorative purposes. They are also used in street car lighting.

When incandescent lamps are to be used in series, they should be carefully selected; there is quite a difference in the current consumed by different lamps, even of the same make, and when they are all limited to the same current quite a difference in candlepower may be noticeable. Some will be above their rated candlepower and others below.

The resistance of an incandescent lamp when cold is very high, varying in the ordinary 16 candlepower 110 volt lamp from 600 to 1,000 ohms. When the lamp becomes heated, as when current is passing through it, the resistance reduces considerably, being in the 16 candlepower 110 volt lamp about 220 ohms.

The current required by the various incandescent lamps varies considerably for lamps of the same voltage and candlepower, but a good average which can be used in figuring currents is ½ ampere for a 16 candlepower 110 volt lamp and ¼ ampere for the 220 volt 16 candlepower lamp. The amount of power, in watts, consumed by a lamp is equal to the voltage multiplied by the current, or W = C × E. A 16 candlepower 110 volt lamp taking ½ ampere would consume 110 × ½ = 55 watts, while a 220 volt lamp taking ¼ ampere would consume 220 × ¼ = 55 watts. It will thus be seen that while the current and voltage may vary, the amount of power consumed will be approximately the same for all 16 candlepower lamps. Lamps are rated at a certain number of watts per candle, the amount varying from 3 to 4 watts for 16 candlepower 110 volt lamps. The proper lamp to be used varies according to the conditions. While less power is consumed in a 3.1 watt lamp, the life of the lamp is comparatively shorter, so that the lamps will have to be renewed oftener. With a 4 watt lamp a greater amount of current is consumed, but the life of the lamp is longer. Another point of great importance in burning incandescent lamps is the voltage. The table below shows what effect variation in voltage has on the candlepower and efficiency.

An increase in voltage increases the candlepower. This increases the efficiency and shortens the life as follows:

A lamp burning at—

Normal voltage gives	100	per cent. C. P. and consumes	3.1	Watts per C. P.
1 per cent. above normal gives	106	per cent. C. P. and consumes	3.	Watts per C. P.
2 " " " " "	112	" " " " "	2.9	" " "
3 " " " " "	118	" " " " "	2.8	" " "
4 " " " " "	125	" " " " "	2.7	" " "
5 " " " " "	132	" " " " "	2.6	" " "
6 " " " " "	140	" " " " "	2.5	" " "

A lamp burning at normal voltage should give its full candlepower at its rated efficiency. A 3.1 watt lamp burning below its voltage loses its efficiency and candlepower as follows:

If burned—

1	per	cent.	below	normal	it	gives	95	per	cent.	C. P.	and	consumes	3.2	Watts	per	C. P.
2	"	"	"	"	"	"	90	"	"	"	"	"	3.35	"	"	"
3	"	"	"	"	"	"	85	"	"	"	"	"	3.5	"	"	"
4	"	"	"	"	"	"	80	"	"	"	"	"	3.6	"	"	"
5	"	"	"	"	"	"	75	"	"	"	"	"	3.75	"	"	"
6	"	"	"	"	"	"	70	"	"	"	"	"	4.	"	"	"
10	"	"	"	"	"	"	50	"	"	"	"	"	4.6	"	"	"

By referring to the table it will be seen that with the voltage raised 3 per cent. (on a 110 volt system to a little over 113 volts) the candlepower will increase 18 per cent., or in other words, a 16 candlepower lamp would be raised to nearly 19 candlepower. At the same time raising the voltage will decrease the life of the lamp. This is shown in the following table where, with an increase of 6 per cent. in the voltage, the life of the lamp is reduced 70 per cent. A lamp at normal voltage has 100 per cent. life.

The	same	lamp	1	per	cent.	above	normal	loses	18	per	cent.	life.
"	"	"	2	"	"	"	"	"	30	"	"	"
"	"	"	3	"	"	"	"	"	44	"	"	"
"	"	"	4	"	"	"	"	"	55	"	"	"
"	"	"	5	"	"	"	"	"	62	"	"	"
"	"	"	6	"	"	"	"	"	70	"	"	"

To obtain satisfactory results, the voltage should be kept constant at just the proper value.

Considerable heat is generated in an incandescent lamp, so that as a general rule it is a bad plan to use paper shades which come very close to the bulb. Where lamps are hung so that there is a liability of their coming in contact with surrounding inflammable material, such as in warehouses and store-rooms, it is a good plan to enclose the lamp in a wire guard.

The following table will prove a handy reference for estimating the number of lamps (8 to 50 C. P.) that can be run per horsepower or kilowatt. The table is figured for theoretical values, so that the actual horsepower or kilowatts delivered must be used, or else values less than those given must be used to allow for loss in the lines.

Candle-power.	Efficiency.	Total Watts.	Per Horsepower.	Per Kilowatt.
8	3.5	28	26.6	35.7
8	4	32	23.3	31.2
16	3	48	15.5	20.8
16	3.1	50	14.9	20
16	3.5	56	13.3	17.8
16	4	64	11.6	15.6
20	3	60	12.4	16.6
20	3.1	62	12	16.1
20	3.5	70	10.6	14.2
25	3	75	9.9	13.3
25	3.1	77.5	9.6	12.9
25	3.5	87.5	8.5	11.4
25	4	100	7.4	10
32	3	96	7	10.4
32	3.1	99.2	7.5	10
32	3.5	112	6.6	8.9
50	3	150	4.9	6.6
50	3.1	155	4.8	6.4
50	3.5	175	4.2	5.7

The first column gives the candlepower. The second column gives the number of watts consumed for each single candlepower obtained, and is called the efficiency of the lamp. Multiply the total candlepower by the efficiency and you get the total number of watts consumed by the lamp. The fourth column shows the number of lamps per 746 watts, and the last column the number of lamps per 1,000 watts.

The current and watts consumed by 110 volt lamps of the different candlepowers are approximately given below.

4	candlepower	0.18	amperes,	20	watts
8	“	0.29	“	32	“
16	“	0.5	“	55	“
32	“	1.0	“	110	“

The light given off by an incandescent lamp varies according to the position from which it is viewed. In some makes of lamps most of the light is given off directly downward, while in other lamps the maximum light is given off in a horizontal direction. The best lamp to use must be determined by the location of the lamp and the place where the light is required. By the use of suitable reflectors or shades the light can be thrown in any direction desired. A 16 candlepower lamp if placed seven feet above the floor will light up a floor space of 100 sq. ft., providing the walls are of a light color. If the walls are of a dull color, or if a bright illumination is desired more lamps should be used. Glass globes placed over the lamps reduce the light to a considerable extent, as is shown in the following table:

Clear glass	10	per cent.
Holophane	12	"
Opaline	20 to 40	"
Ground	25 to 30	"
Opal	25 to 60	"

CHAPTER XI

The Nernst Lamp. Very recently a new type of electric lamp has been introduced which has a few characteristics of the arc lamp and many of the characteristics of the incandescent lamp. It is a lamp that can be successfully operated only on alternating currents. That part of the lamp from which the light is emitted is called the glower. The glower performs about the same functions as does the filament in an incandescent lamp.

In Fig. 99 a diagram of a six glower lamp is shown. The six glowers are shown at 6. These glowers are in the shape of small rods and are composed of an oxid which, at the normal temperature, is of very high resistance, the resistance being so high that practically no current can flow through them. When these rods become heated, the resistance reduces considerably, so that they will conduct current. The heaters which are composed of a considerable length of fine platinum wire embedded in porcelain, are shown at 5. The action of the lamp is as follows: Current enters at 1, and being unable to flow over the glowers on account of their high resistance, passes to the cutout 4′, then through the platinum wire of the heaters back to the other side of the cutout 4. As the platinum wire in the heaters becomes heated, the glowers, which are placed directly below them, also heat up and in time their resistance becomes so reduced that current will pass through them. The current will now pass through the glowers to what is known as the ballast, 7. This ballast is composed of fine iron wire and its purpose is to steady the current through the glower. From the fact that iron wire increases in resistance with increase of current, this wire acts as a regulator, tending to cut down any fluctuations in the current strength. It will be noticed that there is a separate ballast for each glower. From the ballast the current flows around the coil of wire 3. Inside of this coil is an iron core which

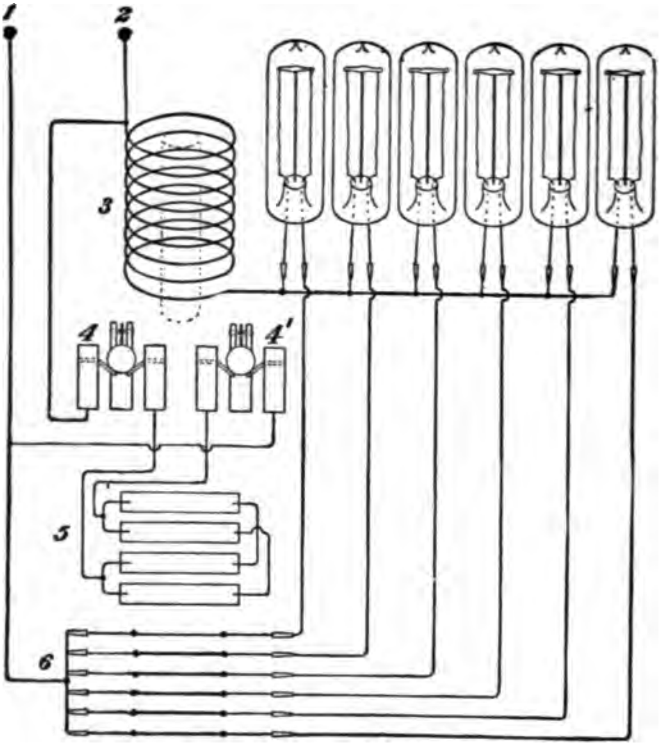


FIGURE 99.

moves up and down, and connected to the lower end of this core are the cutouts 4,4′. As the glower becomes heated, more current is sent around this coil, until it becomes of such strength that the core is drawn in, thus opening the cutouts. All of the current will now flow through the glowers. The Nernst lamp does not operate successfully on direct current, due to the blackening of the glower caused by decomposition of the platinum contacts with which they are connected. These lamps are made in sizes of from 1 to 30 glowers, and they consume about 88 watts per glower. The light resembles very closely the light from a Welsbach gas burner, although the green tinge of the Welsbach is not present.

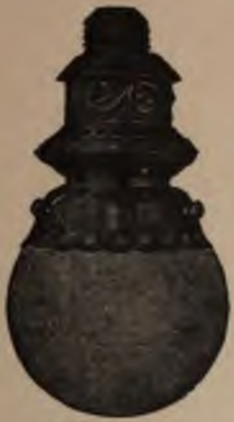


FIGURE 100.

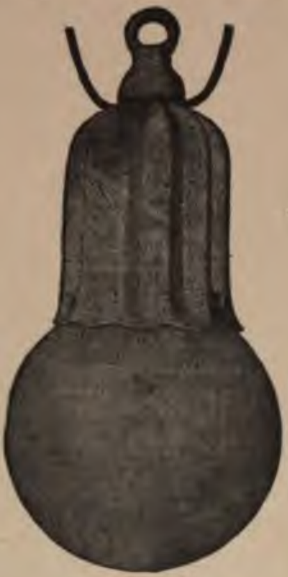


FIGURE 101.

In Fig. 100 is shown the single glower lamp assembled, which can be inserted in an ordinary Edison socket.

In Fig. 101 the six glower lamp, with dome attached, is shown.

CHAPTER XII

Line Testing. In the operation of electric light and power circuits three principal causes of trouble are continually encountered. These are the open circuit, the short circuit, the ground, and also combinations of these, as there is nothing which prevents the existence of all three defects on any line at the same time. In order to study these properly, let us refer to Fig. 102, which shows an ordinary incandescent circuit equipped with the necessary cutout and a switch.

An open circuit may be caused by poor contact, or failure to make any contact at all, of the fuse. If this is the cause, the light can be made to burn by connecting the fuse terminals A and B or C and D by means of short pieces of wire. Such wire must, however, be used only for an instant to make sure of the trouble, and proper fuses must then be provided. Another method of locating an open circuit in the fuse consists of moistening the finger tips and placing the tips of two fingers of the same hand on B and D. If the fuses are in order, a slight shock will be felt; this method is applicable only on low voltage systems and must never be used where the voltage exceeds 250.

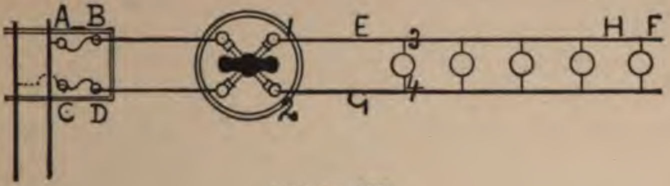


FIGURE 102.

If the fuses are found all right, the next place to look for the cause of an open circuit is at the switch. The contact points of switches are often so badly burned or covered with dirt and grease that they do not make proper connection and hence the lights will not burn.

The switch can be tested with the fingers just as we tested the cutout, and if the shock is felt the line is all right to this point. In testing the switch, be sure you test at the proper point (1 and 2) in the figure which shows a switch, the blades of which cross. Some switches make connection straight along without crossing. In testing with a wire, as shown above, be very careful not to connect the points 1 and 2 at the switch, or you will have a short circuit.

If the line is found alive at the far side (points 1 and 2) of the switch shown, and still the lights do not burn, it is quite likely that there is a broken wire between the switch and the lamps. This break in the wire is not always visible, as often the wire is entirely concealed, and even when the wire is in plain view, the break may extend only to the copper and leave the outer insulation apparently perfect.

If we are dealing with concealed wires that appear only where the lights are connected, we must first examine the connections at all such places and see whether they are in good order. If we find nothing wrong there we may proceed to locate our open circuit (which we shall assume to be at E) by the following method: In place of one of the fuses AB or CD, connect any incandescent lamp (if plug cutouts are used the lamp can be screwed in instead of the plug). Now connect a wire from 1 or 2 of the switch to 3 or 4 of the nearest lamp.

If we happen to connect our wire from 1 to 4 we shall make a short circuit and the lamp at the cutout will burn at full candlepower, but none of the other lamps will burn at all. Now disconnect the test wire from 4 and connect it at 3; if the broken wire is at E, as we have assumed, all the lights will now burn in series with the lamp in the cutout. If there are but few lights connected in the circuit, this lamp will burn at about half candlepower; if there are many lamps connected it will come nearly to full candlepower, and the lamps in the circuit will show nothing.

If instead of an open circuit the cause of our trouble is a short circuit, it will first make itself evident by a burned out fuse in the cutout at AB or CD.

A little experience will soon enable one to judge whether a burned out fuse is due to an overload or a short circuit; the damage to terminals and the evidence of burning will be much greater from a "short" than from a slight overload.

Often the current that "blows" the fuse will also burn out the wire which caused the "short," so that the line will seem perfectly clear when a new fuse is inserted.

If an inspection of the wires and apparatus does not reveal the location of the trouble, we may fuse up one side of the circuit and connect an incandescent lamp in place of the other fuse. If the "short" is still on, the lamp will burn at full candle power.

A short circuit may consist of anything of low electrical resistance that brings the wires of opposite polarity into electrical connection with each other. Thus, if the two points, F and G, although several hundred feet or even yards apart, were in connection with gas or water piping of low electrical resistance, all current would flow through the piping from F to G, and there would be none to flow through the lamps. Short circuits are also often caused by small wires inside of sockets or fixtures coming in improper contact. In one instance a short circuit which caused a search of several hours was finally located in the butt of an Edison base lamp, the center contact piece of which had been put on crooked in such a manner that when the lamp was screwed into its socket this center piece made connection with opposite poles within the socket.

If a careful examination does not reveal the "short" it will be necessary to cut the wires, say at H; if this clears the line so that all lamps nearer the cutout than H burn, the trouble must be beyond H; if not, the line must be cut again nearer the cutout until finally the exact location of the trouble is found.

Any connection of any part of an electrical circuit to *earth* is called a "ground," and wires so connected are said to be grounded. One ground on a system will not necessarily do much harm or interfere with the operation of the system. It will, however, greatly increase the probability of electric shocks to people coming in contact with any part of the wiring. Also, if there is a ground on one side of a system, the appearance of a second ground on the other side of the system will be equal to a short circuit, if both are of low resistance, and probably cause the burning out of fuses or wires.

If a ground is of high resistance, it may merely waste energy through leakage of current; or it may cause slow destruction of a wire or sometimes a gas or water pipe by electrolytic action. Aside from direct contact with metal parts of buildings, the most prolific cause of grounds is found in dampness.

Grounds may be located by means of the Wheatstone bridge, magneto or a common bell and battery. After removing the fuses from the grounded part of the system, connect one side of the apparatus to a good ground, such as a water pipe, and the other side to the system. Proceed in the same way as explained for short circuits; that is, cut the lines until the ground is located, or the line shows clear. Where the wiring is concealed and there are a number of switches controlling chandeliers, grounds can very often be located by switching off one fixture at a time, for when the grounded fixture is switched off the line will show clear.

To facilitate the discovery of grounds as soon as they come on, most switchboards are equipped with ground detectors of some kind.

The cheapest and easiest to install of these consists of two lamps in series, as shown in Fig. 103. So long as both sides of the system are clear of grounds, the lamps will both burn at equal candlepower (rather dim) no matter whether the buttom C be pressed or not. But should a ground come on the + wire, say at B, and the button C be then pressed, the lamp 2 will be deprived of current and lamp 1 will burn at full candlepower. In such a case the current passes from the + wire to the ground B, through the ground to C,

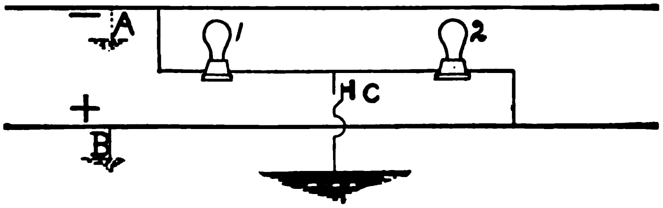


FIGURE 103.

button C and lamp 1 to the – wire. Should a ground come at A, lamp 1 would be cut out and 2 would

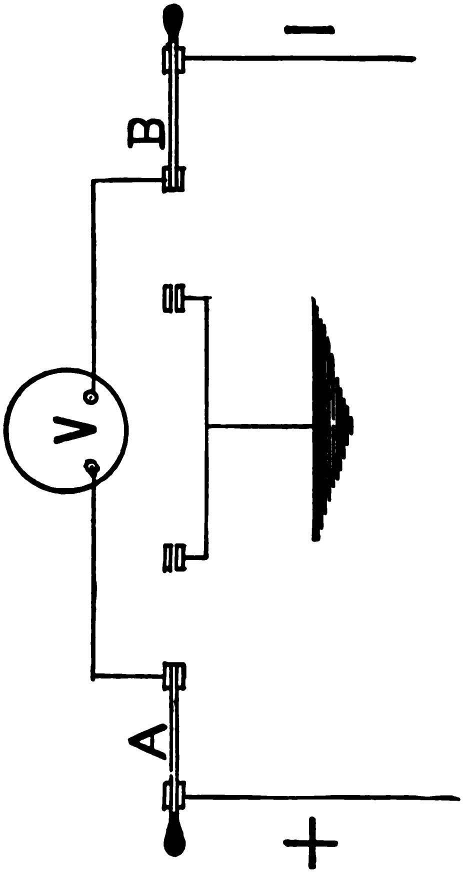


FIGURE 104.

burn at full candlepower. The great disadvantage of the lamp ground detector lies in the fact that it is not very sensitive; that is unless the ground is of quite low resistance the difference in the brilliancy of the lamps will hardly be noticeable.

A much more satisfactory arrangement is that shown in Fig. 104, where a voltmeter is connected for that purpose. With the two single pole switches A and B in the position shown, the voltmeter indicates the pressure of the dynamo; if B is thrown over, the current from the + wire passes through the voltmeter to the ground, and if there is a ground on the – wire it will indicate it. If B is thrown back and A over, a ground on the + wire will be indicated. If the system is perfectly clear, the voltmeter will indicate nothing with either one of the switches thrown over. This test of lines and circuits should be quite frequently made.

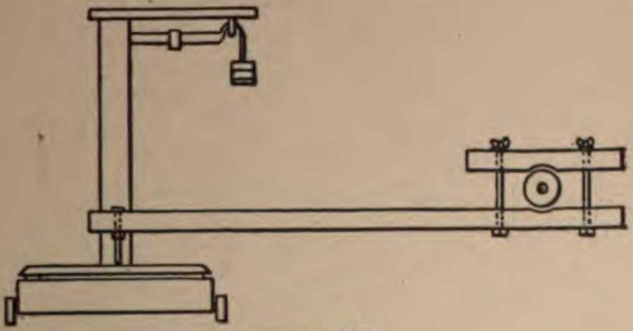


FIGURE 105.

Testing Efficiency of Dynamos and Motors. The simplest means of testing the efficiency of motors is shown in Fig. 105.

This is known as the Prony brake, and consists of a pair of clamps arranged for thumb screws and fastened to the pulley of the motor, and a set of scales.

We will assume that we are testing the efficiency of a motor. We will arrange the clamps over the pulley as shown in the figure and on the long end of the clamp we will arrange a bolt, from which we may impart the pressure obtained to the platform of a pair of scales. In the circuit supplying the motor with current we will connect an amperemeter and a voltmeter. We will now start the motor and press down on the clamps by means of the thumb screw, until the mechanical energy expended is sufficiently high to cause the desired consumption of current shown by the amperemeter at the pressure shown by the voltmeter. With a tachometer or speed indicator we will find the number of revolutions of the motor per minute. When this has been done, we will take the weights on the scales and balance the pressure brought down on the platform. Now stop the motor. The weight indicated by the scales is that weight which the motor would have revolved through a circle, the radius, or half the diameter of which is the distance from the center of the motor shaft to the center of the bolt pressing on the scale platform, Fig. 105. To find the horsepower exerted, multiply the distance between the bolt and the armature shaft by 2. This will be the diameter of the circle described. Multiply this by 3.1416. This will be the circumference of the circle described. Multiply this by the number of pounds indicated by the scales, multiply this by the number of revolutions per minute, and divide the answer by 33,000.

Suppose your amperemeter registered 50.9 amperes and your voltmeter registered 110 volts. This would be 50.9 x 110 = 5,599 watts consumed. Divided by 746 watts, the electrical horsepower would be 7½ horsepower consumed.

Suppose the dynamometer proved that you obtained six actual mechanical horsepower. Then 6 divided by 7½ would be 80 per cent. efficiency which the motor would have for changing electrical energy into mechanical energy.

To test the efficiency of a dynamo we must first find how much power is being delivered to it by the engine. This is done in the usual manner by means of the indicator, etc. Having obtained this, it is simply necessary to connect an ammeter and voltmeter and, taking simultaneous readings of both, find the power given out by the dynamo by multiplying together the volts and amperes.

As an example, suppose we have found that our engine is delivering 40 H. P. while we are obtaining from our dynamo 200 amperes at 110 volts pressure. 200 × 110 divided by 746 will give us the electrical energy we are receiving; in this case a trifle less than 29.5 H. P. To find the efficiency of the dynamo we divide the power received from the dynamo by that delivered to it by the engine, 29.5 divided by 40 equals .737, which is the efficiency of this dynamo. When testing dynamos it is usual to provide an artificial load which can be kept constant. Large metal plates, preferably copper, are connected to the positive and negative mains of the dynamo and immersed in a barrel of water. The quantity of current that will flow from one plate to the other can be regulated by dissolving more or less salt in the water and by immersing the plates more or less and also by bringing them closer together. The greater the surface of the plates immersed in the water and the nearer they are brought together, the greater will be the current. Be very careful and do not let the plates touch each other. Before accepting a new dynamo a test run of twenty-four hours at full load is usually made and the water rheostat need be used only to keep the load constant when lights are switched on or off.

Photometer. The amount of light given off by an incandescent lamp is measured in candlepower. To determine the candlepower of a lamp, an apparatus known as the photometer is used. Fig. 106 shows a diagram of what is known as the Bunsen photometer. S is a scale divided into inches, meters, or any suitable divisions, at one end of which is placed a standard lamp and at the other end the lamp to be measured.

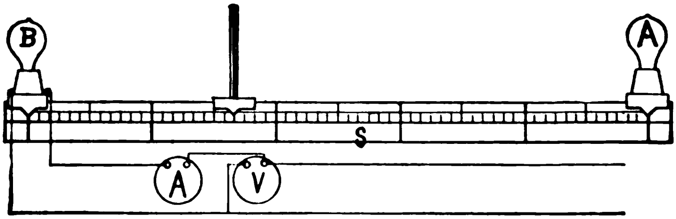


FIGURE 106.

A small screen, made of white paper having a grease spot in the center, is mounted on a stand so that it can be moved along the scale. To operate the instrument, move the screen to such a point that the grease spot becomes invisible from either side. The two candlepowers are now to each other as the squares of their distances from the screen. For instance, suppose the lamp A is a standard 16 candlepower lamp and at the point where the grease spot is invisible the distance from B to the screen is 20 in., and from A to the screen 40 in., then B is to A as 20 squared is to 40 squared, or as 400 is to 1,600 or one-fourth as great; therefore B is a 4 candlepower lamp. Care must be taken that the two lamps are burning at just the proper voltage, otherwise the comparison will not be accurate. Instruments of the kind just described are made in a variety of different patterns, but their principle remains the same. Candlepowers may also be compared by a method known as Rumford's. Take a pencil or other opaque rod and place it in front of a white piece of paper or light-colored wall. Now place in front of it, but separated so that there will be two separate shadows cast, the two lamps to be compared. By moving one of the lamps away from, or closer to, the screen, at some point the two shadows will become of the same density. Now measure the distances of the two lamps from the screen, and their candlepowers will be to each other as the squares of the distances; (Fig. 107).

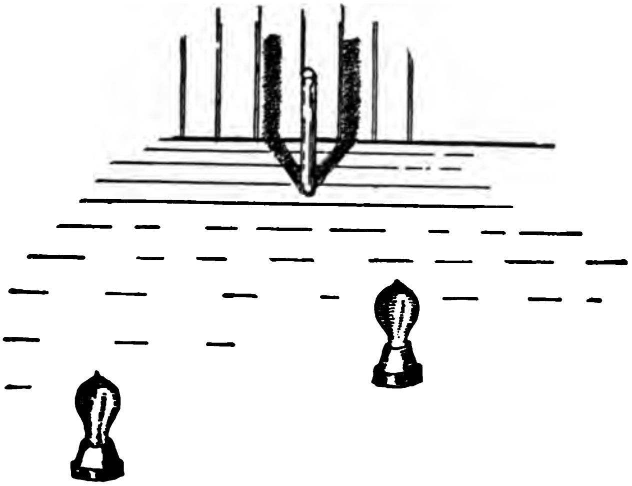


FIGURE 107.

If the current consumed by a lamp and the voltage maintained at its terminals are measured by an ammeter and voltmeter, as shown in Fig. 106, we need only find the watts (current times volts) and divide by the candlepower to find the efficiency of the lamp. If, for instance, the 4 candlepower lamp B is taking $\frac{1}{6}$ ampere at 110 volts, we have $18\frac{1}{3}$ watts expended on it; this divided by the candlepower 4 shows an efficiency of $4\frac{7}{12}$ watts per candle.

CHAPTER XIII

Storage Batteries. The storage battery is often referred to as an accumulator. An accumulator is an appliance for storing electricity. It depends upon the chemical changes undergone by certain substances when subjected to the action of an electric current. Strictly speaking, it is not correct to say that electricity is stored in an accumulator, although as far as external results is concerned such appears to be the case. What it really does is this: The current flowing into the accumulator produces a gradual chemical change or decomposition of the active elements of which the battery is constructed. This change continues to take place as long as the charging current is applied. This is known as electrolytic action. As soon as the current ceases, so also does the chemical decomposition of the elements cease, and if the terminals be then connected by a wire, a reversal of the chemical process commences. Particles gradually reform themselves into original chemical combinations, and by so doing produce a current of electricity which flows in opposite direction to that originally used for charging.

An early form of accumulator, though more of experimental than practical interest, was Grove's gas battery. This was composed of a series of cells, each cell comprising two tubes, closed at the upper ends, and dipping down into a glass jar containing acidulated water. Each tube had a platinum wire fused into the closed end, from which a strip of platinum foil extended downwards into the liquid. The outer ends of the platinum wires were provided with terminals, by means of which several of these cells were connected together. A charging current was then applied and resulted in the gradual decomposition of the water in the various glass jars. Hydrogen collected on one of the platinum plates in each of the cells and oxygen on the other. If after a short time the charging source was disconnected from the wires joined to the outer terminals of the cells and a galvanometer substituted, it was found that a current would then flow in the reverse direction until all the separated hydrogen and oxygen gases had recombined to form water again.

From a practical point of view the gas battery was deficient, inasmuch as it would only supply current for a very short time, and several workers set themselves the task of contriving an arrangement to obviate this defect. The most successful of these early workers was Plante, and he found in the course of his experiments that the best results were to be obtained by using lead plates or electrodes in a dilute solution of sulphuric acid. He made a cell by taking two long strips of sheet lead, placed one over the other with pieces of insulating material between, and coiling these up into spiral form. These plates were provided with separate terminals and were placed in a jar containing a solution of sulphuric acid. The action of the charging current was to decompose the water in the solution, the oxygen combining with the metal of the positive plate and thus forming peroxide of lead, whereas the hydrogen was simply deposited on the negative plate and there remained in gaseous form. On discontinuing the charging current, the hydrogen combined with the oxygen in the solution to form water again, while the peroxide of lead was deoxidized, the lead remaining on the surface of the plate as spongy lead, and the oxygen reëntered the solution to compensate for the oxygen which was extracted therefrom by the hydrogen in forming water. Plante found that this method of construction enabled him to get an electromotive force of from 2 to 2.5 volts, as against 1.47 volts given by Grove's gas battery.

Plante's experiments did not, however, terminate with this achievement, and he next introduced a method for considerably increasing the available metallic surface of the electrodes. This plan is known as "forming" the plates, and consists of repeating for a considerable time the following series of operations: (1) charge the accumulator, (2) discharge ditto, (3) recharge, but with the charging current entering in the reverse direction, (4) again discharge. This series of reversals in charging and discharging, if kept up for several days, has the effect of causing the lead plates to become very porous or spongy in character, and, therefore, by reason of the additional surface of contact between electrolyte and electrode thus provided, enables the cell to retain a much greater charge than it would otherwise.

It is not difficult to see that this work of forming is of a somewhat tedious and expensive character, and with the object of reducing this process to a minimum, another inventor, Faure, conceived the idea of using plates coated with a paste of lead-oxide, a plan which made it possible to use an accumulator with success after being charged only two or three times. When first introduced, some difficulty was found in making the lead-oxide paste adhere properly to the plates, and various means were devised to overcome this drawback. Scratching and indenting the lead plates was tried, but this was ultimately superseded by the plan of making perforated plates in the form of grids, the paste being pressed into the perforations. With various slight modifications, in the shape of perforations, this device has been found to answer exceedingly well, and is now very generally adopted.

When an accumulator is freshly charged, it would be found to have an electromotive force of about 2.25 to 2.5 volts, but after being used a short time this falls to about 2 volts, at which figure it remains until the cell is nearly exhausted. For many purposes, however, a higher voltage than this is required, and it then becomes necessary to have several cells joined in series, so as to give a total voltage equal to the number of cells multiplied by 2. Thus 20 cells of 2 volts each, if joined in series, would give an electromotive force of 40 volts; 50 cells would give 100 volts, and so on.

The quantity of current which a cell will accumulate or store depends upon the area of its plates; the larger the plates the greater the capacity of the cell, and the higher the permissible rate of discharge. As it is not always convenient to use very large plates where great capacity is required, the same result may be obtained by using a number of small plates to increase the available plate surface, but in such cases the plates must be connected in parallel. That is, the positive plates must all be connected to one terminal, and the negative plates all to the other terminal, thus forming practically two plates divided into a number of branches.

The capacity of an accumulator is usually measured in ampere hours. Thus an accumulator which will discharge a current of ten amperes for one hour, or of five amperes for two hours, or of one ampere for ten hours, is said to have a capacity of ten ampere hours. As a general rule, it may be estimated that an accumulator has a capacity of six ampere hours for each square foot of positive plate surface.

For charging storage batteries the shunt dynamo is generally used, and the voltage must be kept as nearly constant as possible. Fig. 108 shows a very simple installation where the battery is intended to be charged during the running time of the dynamo and to carry the lights during such time as the dynamo is not in action. The ammeter A, in the battery line, should be of a kind which indicates the direction of the current passing through it. The rheostat R is used to regulate the charging current and the voltmeter V is connected so that either the voltage of the dynamo or the battery may be taken. In addition to this voltmeter a low reading meter should also be provided to test single cells. An automatic circuit breaker is also often provided to open the circuit should the current through it flow in the wrong direction. Should, for any reason, the voltage of the dynamo fall below that

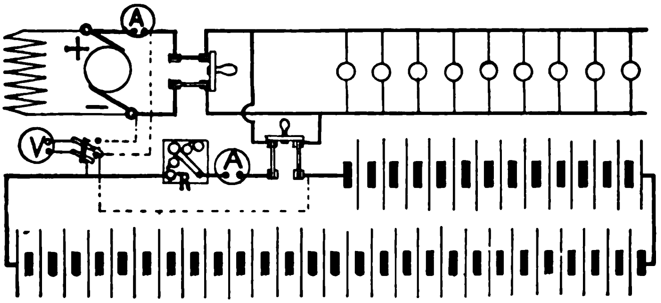


FIGURE 108.

of the battery while charging, the battery would begin to discharge through the dynamo. Where it is important that the voltage supplied by the battery shall be at the same voltage as that supplied by the dynamo, a "booster" is employed to help charge the battery. Such a booster increases the electromotive force at the terminals of the battery sufficient to allow it to be charged to the full pressure of the dynamo. In setting up and charging storage batteries, detailed instructions should be obtained from the makers and rigidly followed.

CHAPTER XIV

Electrolysis. Electrolysis is chemical decomposition effected by means of the flow of an electric current. By electrolytic action it is possible to deposit metals, such as gold, silver, nickel, etc., over the exterior surface of other metals. This process is ordinarily called nickel plating, gold plating, etc., and is carried on by means of tanks in which there are liquids holding in solution some of the various metallic salts. By placing over these tanks a bar or number of bars made of brass or copper, we may hang articles from these bars by means of wires, so that they are submerged in the solution. Now by using a dynamo whose output is low in pressure or electromotive force and high in quantity or amperes, and connecting the positive or outgoing terminal of this machine to a piece of metal, such as copper, nickel, gold, or silver, and submerging this metal in the liquid contained in the tank, the flow of current from this piece of gold or silver into the liquid or bath will carry with it, by electrolysis or electrolytic action, some of this gold or silver and deposit it on the articles suspended in the liquid, from the brass or copper bars to which the negative terminal of the plating dynamo is connected. The use of the bath containing metallic salts reduces the resistance from the metal to be deposited on the articles that are to be plated, which are the negative electrodes. This effects an equal deposit of metal over the entire surfaces being subjected to the electrolytic or plating action.

Where it is desired to cover such metals as steel or iron with silver or gold, it becomes necessary to subject the articles to be plated to what is called a striking bath. This striking bath consists of a system of electrolytic action as above described, where copper is first deposited over the surfaces of iron or steel. The more precious metals will distribute themselves over this copper surface more uniformly and in a finer grained manner than if the article had not been copper plated first. After the plated article has had sufficient metal deposited on its surface, it is put through a buffing and polishing process for its final finish.

Electrolysis has also been applied where it is desired to reclaim the precious metals from ores without smelting them. This method consists of immersing the ore in tanks filled with a solution. The ore receives current from the positive element of a dynamo through the liquid solution, and the metal in the ore is deposited on the negative plate in the vat, which is connected to the negative terminal of the dynamo. Thus by employing a process similar to electro plating it is possible to extract the metal from the ores in almost its pure state from the negative plate. The solution mentioned is water in which various kinds of metallic salts have been dissolved which bear a chemical relation to the metals to be extracted.

This short description will assist in explaining how electrolytic action takes place in water and gas pipes buried under the surface of the ground, when, for instance, electric railroads, operated in the vicinity are not properly constructed. In the construction of an electric street railroad or trolley line the generators are connected to the trolley wires usually at the positive terminals of the dynamos.

The current passes from the trolley line through the car to the rails and back to the negative pole of the dynamo. If the rails are not of sufficient carrying capacity, or if there is a pipe line of better carrying capacity near the rails, it is quite certain that some of the current will be carried by the pipes. Wherever the current leaves a pipe it carries some of the metal with it, and if there is much current a hole will soon be eaten into the pipe. As the pipes are mostly covered with rust, which is a partial insulator, the current will be most likely to enter and leave the pipe at some point which is comparatively bright and the electrolytic action will be concentrated at such points.

Heating by Electricity. The electric heater is simply a coil of wire through which enough current is caused to flow to produce quite an appreciable amount of heat. In the use of resistance coils for nearly all electrical purposes the function of the resistance coil is to cut down the flow of current required at some point, as for instance, where a resistance coil is used as a starting box on a motor. The flow of current across or through such a coil or coils, will produce heat, and shows one way in which electric power can be converted into heat. Another instance, if a contact is poorly made, the resistance to the flow of current offered by this contact produces heat and a consequent loss of watts. The voltaic arc in an arc lamp is another instance where resistance to the flow of current is interposed in the circuit and consequently produces heat.

The incandescent lamp is another instance where resistance is the cause of the production of heat, but, of course, in both the arc and incandescent light, the result desired is a maximum amount of light with a minimum amount of heat.

If we were to construct a coil of small wire, whose total resistance would be the same as that of another coil of large wire, it would be found that the coil of small wire would contain much less wire than the coil of large wire, both resistances being the same in ohms. Now if both these coils were connected across a circuit, we will say of 110 volts, the same amount of current would flow over both the coils, because their resistances are alike, but the smaller coil would get quite hot, while the larger coil would perhaps be just slightly warmed. The number or quantity of heat units given out by both coils are the same. The surface from which these heat units pass out into the atmosphere is much less in the smaller coil than in the large one, hence the smaller coil gets quite hot, sometimes even red hot. If we were to permit current to flow over this small coil and maintain its temperature at a low red heat, it would in time become oxidized by the chemical action of the oxygen in the air. To prevent this oxidization we may imbed this small coil in a porcelain cement, and after it has been properly imbedded in this cement we will put the entire coil and cement through a baking process, making the cement quite hard and sealing the wire coil from the influence of the oxygen in the atmosphere. Then we can take this coil so constructed and produce heat in a flat iron, or in a stove, in a curling iron, soldering iron, and in fact anywhere. The coil being so hermetically sealed it can also be used in chafing dishes, tea kettles, water urns, glue pots, etc. The principle of producing heat by electricity remains the same no matter where or how it is applied, the only difference necessary being in the form given to the heater coils.

Heating by electricity is quite an expensive and uneconomical proposition, and an idea can be obtained as to the quantity of current necessary to do electric heating, when we consider that in very cold weather it requires nearly as much power to operate the heaters in a street car system as it does to propel the cars.

CHAPTER XV

Lightning Arresters. Lightning arresters are needed on overhead, outdoor lines only. The simplest form of lightning arrester consists of two bare metal plates set very close together, but under no circumstances allowed to touch each other. (See Fig. 109.) One of these plates is connected to the overhead line and the other to the ground.

A sudden flow of current meets with an enormous opposition when it encounters the coils of a large electro magnet. Although the resistance of the air space between the two plates forming the lightning arrester may be several millions of ohms, it is far easier for the current to jump this air space in such a very short time as is taken up by a lightning discharge than it would be to force its way around the coils of the magnet. The reason for this is, that a current of electricity flowing through the coils of an electro magnet creates magnetism or lines of force. These lines of force cut through the coils on the magnet and in that way tend to produce a counter current, or counter electromotive force, which, for a very short time, is almost equal to the electromotive force creating it. Were the current flow to continue for any appreciable time this counter electromotive force would disappear entirely as soon as the magnetism reached its final strength.

In order, therefore, to facilitate as much as possible a lightning discharge towards the ground and away from the machinery and buildings, the wires leading from the arresters to the earth should be run in as straight a line as possible and be kept well separated from metal parts, especially iron, of the building. Under no circumstances should the ground wire be run in an iron pipe, nor should lead covered wires be used.

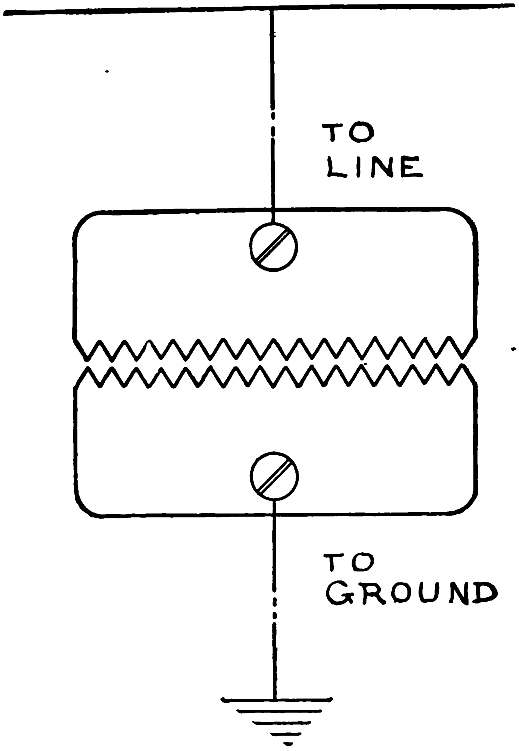


FIGURE 109.

With the simple lightning arrester shown above there is great liability of the current from the dynamo following the arc caused by the lightning discharge to ground, and, as there must be two arresters, one on each side of the dynamo, this amounts almost to a short circuit and is very likely to put the dynamo out of service. Should such an arc continue for a few minutes, it may fuse the plates of the arrester. The arc can readily be extinguished by blowing it out or causing a strong blast of air to strike it.

To prevent trouble of this kind the Thomson lightning arrester, shown in Fig. 110, was devised. This consists of the two diverging metal plates shown at the top of the figure, one of which is connected to the earth and the other to the line to be protected and an electro magnet, as shown. The current from the dynamo traverses the coils of the electro magnets. The action is as follows: When a lightning discharge through the arrester takes place, it forms an arc

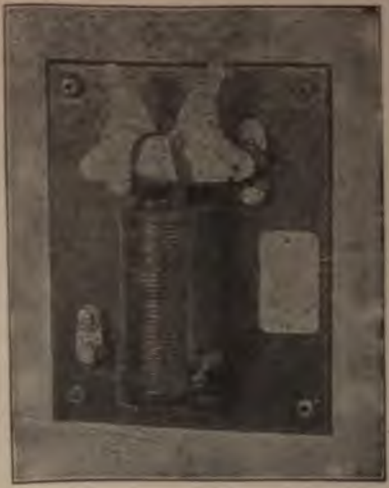


FIGURE 110.

between the lower points of the plates above the magnets. These plates are very close together at the bottom. Now the electric arc is always strongly repulsed by a magnet, and hence the arc formed is forced upward where the plates diverge, and the space becomes too great for it to be maintained and it is then broken. The arc is virtually blown out by the magnetism.

NOTICE.—DO NOT FAIL TO SEE WHETHER ANY RULE OR ORDINANCE OF YOUR CITY CONFLICTS WITH THESE RULES.

CLASS A.

STATIONS AND DYNAMO ROOMS.

Central Stations, Dynamo, Motor and Storage-Battery Rooms, Transformer Substations, Etc.

1. Generators.

a. Must be located in a dry place.

Perfect insulation in electrical apparatus requires that the material used for insulation be kept dry. While in the construction of generators the greatest care is taken, so that all current carrying parts are well insulated, still, if moisture is allowed to settle on the insulation, trouble is almost sure to occur. For this reason a generator should never be installed where it will be exposed to steam or damp air, or in any place, where through accident, water may be thrown against it.

b. Must never be placed in a room where any hazardous process is carried on, nor in places where they would be exposed to inflammable gases or flyings of combustible materials.

In even the best constructed dynamos there is always more or less sparking at the brushes and small pieces of hot carbon are sometimes thrown off. As a general rule in buildings where there is considerable dust, such as in wood-working plants, grain elevators and the like, the dynamo is located in the engine room, which is generally isolated from the dusty part of the building.

c. Must be thoroughly insulated from the ground wherever feasible. Wooden base-frames used for this purpose, and wooden floors which are depended upon for insulation where, for any reason, it is necessary to omit the base-frames, must be kept filled to prevent absorption of moisture, and must be kept clean and dry.

Where frame insulation is impracticable, the Inspection Department having jurisdiction may, in writing, permit its omission, in which case the frame must be permanently and effectively grounded.

A high-potential machine, which on account of great weight or for other reasons, cannot have its frame insulated from the ground, should be surrounded with an insulated platform. This may be made of wood, mounted on insulating supports, and so arranged that a man must always stand upon it in order to touch any part of the machine.

In case of a machine having an insulated frame, if there is trouble from static electricity due to belt friction, it should be overcome by placing near the belt a metallic comb connected with the earth, or by grounding the frame through a very high resistance of not less than 300,000 ohms.

The smaller generators are usually insulated on wooden base-frames. A base-frame suitable for this work is shown in Figure 111. Almost any kind of wood, well varnished, is very good for this purpose. The base-frame is screwed to the floor or foundation and the slide rail (which is used where the dynamo is belted to the engine to allow the tightening and slackening of the belt) is independently attached to it, that is, the same bolt must not be used to hold the slide rail to the base-frame and the base-frame to the floor, as this would be liable to ground the frame. The direct connected machines (dynamo and engine on same bed plate) are often insulated by the use of mica washers and bushings surrounding the bolts which fasten the dynamo to the bed plate and by using an insulated flange coupling between the shaft of the dynamo and that of the engine. Figure 112 shows a section of a flange coupling insulated in this way, the heavily shaded parts representing the insulating material.

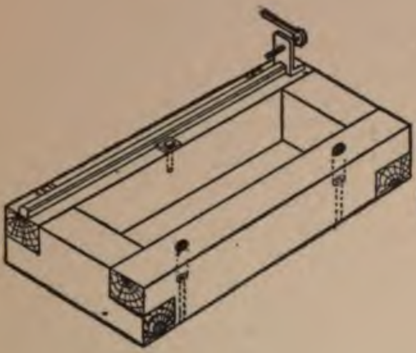


FIGURE 111.

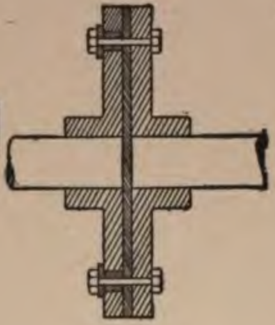


FIGURE 112.

The larger machines, which on account of their weight cannot be insulated, must be permanently and effectually grounded. Where the engine and dynamo are direct connected a very good ground is obtained through the engine connections. Where belts are used a good ground can be obtained by fastening a copper wire under one of the bolts on the dynamo and connecting the other end of the wire to available water pipes. In the case of high tension machines, especially series arc, the machine should always be surrounded by an insulated platform so arranged that a man must stand on it in order to touch any part of the machine either live parts or frame and in handling such a machine only one hand at a time should be used. A hardwood platform mounted on insulators will serve very well for this purpose or suitable platforms may be obtained from dealers in electrical supplies.

Figure 113 shows a metallic comb such as is occasionally used to overcome the static electricity due to the friction of the belt. A strip of metal, one end of which is cut with a number of projecting points, is suspended crosswise a short distance above the belt. A wire connects this plate to any suitable ground.

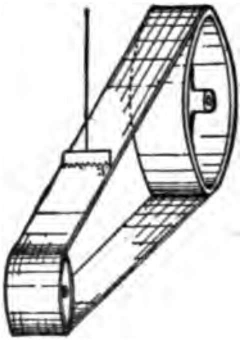


FIGURE 113.

A resistance for grounding the generator frame in accordance with this rule is constructed of ground glass equipped with two metal terminals separated a short distance and connected by means of a lead pencil mark. One terminal is connected to the frame of the machine and the other to the ground.

d. Every constant-potential generator must be protected from excessive current by a safety fuse, or equivalent device of approved design in each lead wire.

These devices should be placed on the machine or as near it as possible.

Where the needs of the service make these devices impracticable, the Inspection Department having jurisdiction may, in writing, modify the requirements.

The fuses required by this rule are often mounted on the dynamo, but the general practice at the present time is to mount all fuses on the switchboard. A fuse should be placed in each lead, that is, each of the main wires from the dynamo should be protected by a fuse. A fuse should never be placed in the field circuit wire. Where two or more dynamos are run in parallel the equalizer connection (a wire connecting all the armature terminals from which the series fields are taken and which tends to equalize the load betwen the various machines) is sometimes carried through a 3-pole switch on the switchboard and is often fused. It is immaterial whether this equalizer is fused or not, as fusing it adds no protection. If it is fused the fuse should be at least the same size as used in the leads.

Circuit-breakers are very often used for the protection in the dynamo leads. They are generally mounted on the switchboard and connected in the circuit ahead of the main switch. As a general rule circuit breakers are not approved unless fuses are also installed in the circuit. The circuit-breaker as at present constructed is in nearly all cases a much more efficient and reliable device than the fuse, and its use is to be recommended. Single-pole circuit-breakers are approved if fuses are also used. As to the relative currents at which the fuse and circuit-breaker should be set to operate, authorities differ. Some advise both to be set to operate at the same current strength, so that the fuse, which takes a longer time to operate, will blow only in case the circuit breaker fails.

Another recommends the fuses to be of such capacity as to carry any load which will be required of them and to set the circuit-breaker a little higher than the fuses, so that the fuses will operate on overload and the circuit breaker on short circuit.

The practice of setting the fuses at about twenty-five per cent above the circuit-breaker seems to be preferred, for it occasionally happens when both are set to operate at the same current, the fuse alone will blow, due to the excessive heat produced in the fuse at full load.

Cases are sometimes found where the cessation of current due to the blowing of a fuse could cause more damage than would result from an overload, as, for instance, where the dynamo operates some safety device. In cases of this kind the Inspection Department having jurisdiction may modify the requirements.

e. Must each be provided with a waterproof cover.

f. Must each be provided with a name-plate, giving the maker's name, the capacity in volts and amperes, and the normal speed in revolutions per minute.

2. Conductors.

From generators to switchboards, rheostats or other instruments, and thence to outside lines.

a. Must be in plain sight or readily accessible.

b. Must have an approved insulating covering as called for by rules in Class C for similar work, except that in central stations, on exposed circuits, the wire which is used must have a heavy braided, non-combustible outer covering.

Bus bars may be made of bare metal.

Rubber and weatherproof insulations ignite easily and burn freely. Where a number of wires are brought close together, as is generally the case in dynamo rooms, especially about the switchboard, it is therefore necessary to surround this inflammable material with a tight, non-combustible outer cover. If this is not done, a fire once started at this point would spread rapidly along the wires, producing intense heat and a dense smoke. Where the wires have such a covering and are well insulated and supported, using only non-combustible materials, it is believed that no appreciable fire hazard exists, even with a large group of wires.

c. Must be kept so rigidly in place that they cannot come in contact.

d. Must in all other respects be installed with the same precautions as required by rules in Class C for wires carrying a current of the same volume and potential.

In wiring switchboards, the ground detector, volt meter and pilot lights must be connected to a circuit of not less than No. 14 B. & S. Gauge wire that is protected by a standard fuse block, this circuit is not to carry over 660 watts.

A number of different methods are used for running wires in dynamo rooms. Where the dynamo is located in a room with a low ceiling, or where it is not desirable to run the wires open, metal conduits may be imbedded in the floor and the wires run in them. If the engine room is located in the basement or in any place where water or moisture is liable to gather in the conduits the wires should be lead covered. At outlets the conduits should be carried some distance above the floor level and close to the frame of the machine, where they will be protected from mechanical injury. If the space under the machine will allow it, the conduit should be ended there where it will be protected by the base frame. Where lead covered wires are used, the lead should be cut back some distance from the exposed part of the wire and the end of the lead should be well taped and compounded so that no moisture can creep in between the lead and the insulation.

In place of the metal conduits tile ducts can be used; or, if the floor is of cement, a channel may be left in the floor and the wires run in it. A removable iron cover should be provided.

The wires may be run open on knobs or cleats as described in Class C. Where there are many wires, cable racks, constructed of wood or preferably iron, having cleats bolted to them, may be used. As a general rule moulding should not be used for this class of work. Especially in central stations the generators are often called upon for a very heavy overload and should the wires become overheated a fire is much more apt to result than if the mains were run open where any trouble could be immediately noticed.

3. Switchboards.

a. Must be so placed as to reduce to a minimum the danger of communicating fire to adjacent combustible material.

Special attention is called to the fact that switchboards should not be built down to the floor, nor up to the ceiling. A space of at least 10 or 12 inches should be left between the floor and the board, and 3 feet, if possible, between the ceiling and the board, in order to prevent fire from communicating from the switchboard to the floor or ceiling, and also to prevent the forming of a partially concealed space very liable to be used for storage of rubbish and oil waste.

b. Must be made of non-combustible material or of hard-wood in skeleton form, filled to prevent absorption of moisture.

If wood is used all wires and all current-carrying parts of the apparatus on the switchboard must be separated therefrom by non-combustible, non-absorptive insulating material.

c. Must be accessible from all sides when the connections are on the back, but may be placed against a brick or stone wall when the wiring is entirely on the face.

If the wiring is on the back, there should be a clear space of at least 18 inches between the wall and the apparatus on the board, and even if the wiring is entirely on the face, it is much better to have the board set out from the wall. The space back of the board should not be closed in, except by grating or netting either at the sides, top or bottom, as such an enclosure is almost sure to be used as a closet for clothing or for the storage of oil cans, rubbish, etc. An open space is much more likely to be kept clean, and is more convenient for making repairs, examinations, etc.

d. Must be kept free from moisture.

e. On switchboards the distances between bare live parts of opposite polarity must be made as great as practicable, and must not be less than those given for tablet-boards (see No. 53 A).

The switchboard may be located in any suitable place in the dynamo room. It should generally be placed in a central position as close as possible, without inconvenience, to all machines and perfectly accessible. Do not locate a switchboard under or near a steam or water pipe or too close to windows, as these may accidentally be the means of wetting the board.

The material generally used for the construction of switchboards is slate or marble, free from metallic veins. If metallic veins are not guarded against they may cause great leakage of current, which will manifest itself in heating the slate or marble.

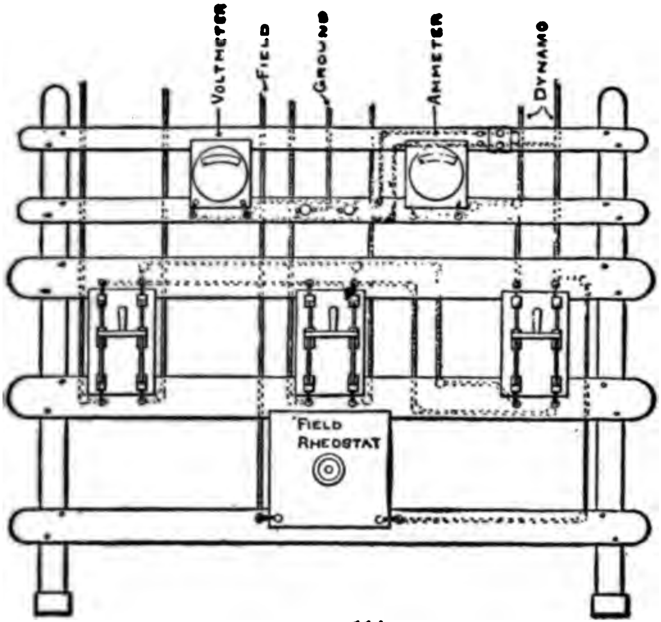


FIGURE 114.

The switchboard may be made of hardwood in skeleton form (see Figure 114), but in this case all switches, cutouts, instruments, etc., must be mounted on non-combustible, non-absorptive insulating bases, such as slate or marble and all wires must be properly bushed where they pass through the woodwork and must be supported on cleats or knobs. Wood base instruments are not approved.

Marble or slate boards are usually set in angle iron frames and are much safer and better than the skeleton board shown. It is a good plan to have the iron legs rest on a wooden base, so that they will be insulated from the ground.

Although only 18 inches clear space is required back of the board, where the board is back connected, this should be increased wherever possible, especially in the case of large boards.

4. Resistance Boxes and Equalizers.

(For construction rules, see No. 60.)

a. Must be placed on a switchboard or, if not thereon at a distance of at least a foot from combustible material, or separated therefrom by a non-inflammable, non-absorptive, insulating material such as slate or marble.

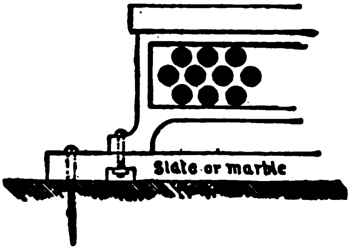


FIGURE 115.

The attachments of the separating material to its support and to the device must be independent of each other, and the separating material must be continuous between the device and the support; that is, the use of porcelain knobs will not be accepted.

Ordinarily the dynamo field rheostat is mounted on the back of the board if the board is back connected, a small hand wheel being provided so that the rheostat may be operated from the front of the board. If the switchboard is in skeleton form, or if the rheostat is placed on a wall, it should be mounted on a solid piece of slate or marble. Separate screws should be used for attaching the rheostat to the slate or marble and the slate or marble to the wall, for, if the same screws were used for this purpose, they would be apt to ground the rheostat frame. (See Figure 115.)

On central stations where current is furnished over a large area, there is on some of the circuits, especially the long ones, a considerable drop, or loss of potential. In order to keep the voltage at the point of supply on these circuits at the proper value, the voltage at the station must be raised. This in turn causes the voltage on those circuits near the dynamo to become excessive. Equalizers, which are large resistance boxes generally constructed of iron wire or strips, and capable of carrying a heavy current, are connected in the circuits and adjusted at such resistances as to make the voltage at the various points of supply uniform. They are generally too heavy to mount on the board, but should be raised on non-combustible, non-absorptive, insulating supports and should be separated from all inflammable material.

b. Where protective resistances are necessary in connection with automatic rheostats, incandescent lamps may be used, provided that they do not carry or control the main current or constitute the regulating resistance of the device.

When so used, lamps must be mounted in porcelain receptacles upon non-combustible supports, and must be so arranged that they cannot have impressed upon them a voltage greater than that for which they are rated. They must in all cases be provided with a name-plate, which shall be permanently attached beside the porcelain receptacle or receptacles and stamped with the candle-power and voltage of the lamp or lamps to be used in each receptacle.

5. **Lightning Arresters.**

(For construction rules, see No. 63.)

a. Must be attached to each wire of every overhead circuit connected with the station.

It is recommended to all electric light and power companies that arresters be connected at intervals over systems in such numbers and so located as to prevent ordinary discharges entering (over the wires) buildings connected to the lines.

b. Must be located in readily accessible places away from combustible materials, and as near as practicable to the point where the wires enter the building.

Station arresters should generally be placed in plain sight on the switchboard.

In all cases, kinks, coils and sharp bends in the wires between the arresters and the outdoor lines must be avoided as far as possible.

c. Must be connected with a thoroughly good and permanent ground connection by metallic strips or wires having a conductivity not less than that of a No. 6 B. & S. Gauge copper wire, which must be run as nearly in a straight line as possible from the arresters to the ground connection.

Ground wires for lightning arresters must not be attached to gas pipes within the buildings.

It is often desirable to introduce a choke coil in circuit between the arresters and the dynamo. In no case should the ground wires from the lightning arresters be put into iron pipes, as these would tend to impede the discharge.

A lightning discharge is simply a discharge of electricity at very high potential. While the insulation of the ordinary wire serves very well for the voltages for which it is used it offers very little resistance to a current of such high potential, and providing the discharge can reach the ground by jumping though the insulation, it will generally take that course unless some easier path is offered to it. A lightning arrester in its simplest form consists of two metal plates separated by a small air space as shown in Figure 116. One of the plates is connected to the line and the other to the ground, a set being provided for each line wire to be protected.

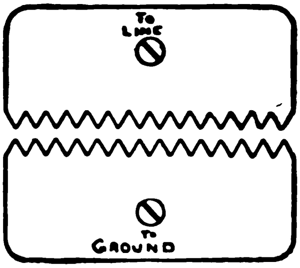


FIGURE 116.

The air space between the metal plates offers a much lower resistance to the passage of such a sudden current as a discharge of lightning consists of, than do the magnets of a dynamo, for instance, or highly insulated parts of the line. The current, therefore, jumps the air space and passes to ground. When the current jumps this air space it produces an arc similar to that seen in an arc lamp, and after the lightning discharge is over the dynamo current is very likely to maintain this arc and thus cause a short circuit from one lightning arrester through the ground to the other. Different methods of preventing this by interrupting the arc have been devised.

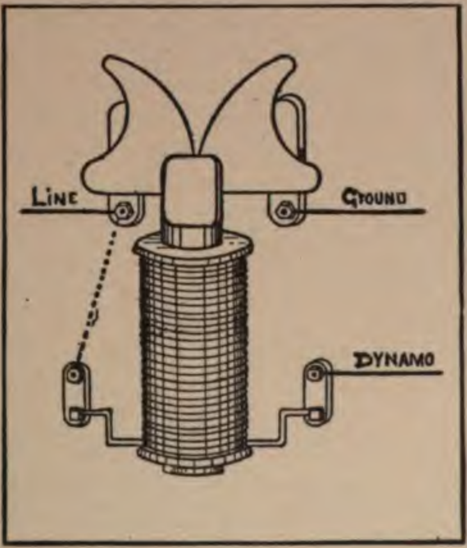


FIGURE 117.

Figure 117. shows the T. H. lightning arrester, in which the arc is extinguished by a magnetic field set up by the electro-magnet. In the Wurts non-arcing lightning arrester (Figure 118) the discharge takes place across the air gaps between the cylinders; these are made of a metal which will not arc.

A choke coil is essentially an electro-magnet, and like all magnets offers a very high resistance to a sudden rise in current strength, and is, therefore, an additional protection to other magnets in the circuit.

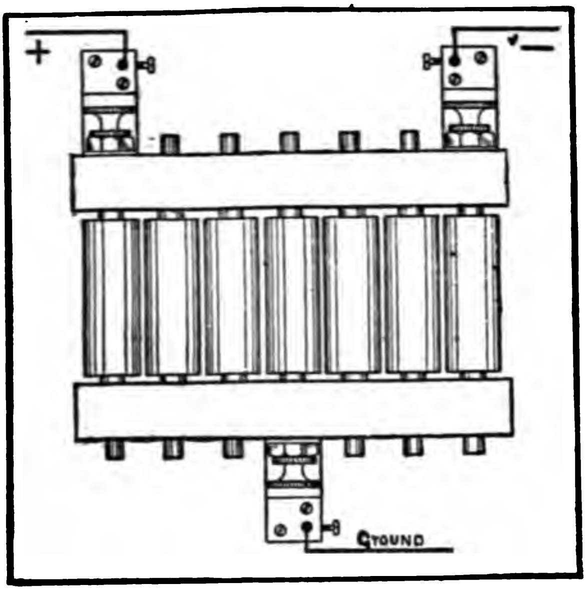


FIGURE 118.

6. Care and Attendance.

a. A competent man must be kept on duty where generators are operating.

b. Oily waste must be kept in approved metal cans and removed daily.

Approved waste cans shall be made of metal, with legs raising can 3 inches from the floor and with self-closing covers.

7. Testing of Insulation Resistance.

a. All circuits except such as are permanently grounded in accordance with Rule 13 A must be provided with reliable ground detectors. Detectors which indicate continuously and give an instant and permanent indication of a ground are preferable. Ground wires from detectors must not be attached to gas pipes within the building.

b. Where continuously indicating detectors are not feasible the circuits should be tested at least once per day, and preferably oftener.

c. Data obtained from all tests must be preserved for examination by the Inspection Department having jurisdiction.

These rules on testing to be applied to such places as may be designated by the Inspection Department having jurisdiction.

The exceptions to this rule are 3-wire direct current systems where the neutral is grounded and 2 and 3-wire alternating current secondaries where the neutral or one side is grounded.

In every installation of electric wiring there is a certain leak of current. This leak is partly between the wires and the ground and between the wires themselves. The amount of leak varies, but is always dependent on the insulation resistance. Where a small amount of wire is well installed the leak should be very small, but in the case of large installations or where the wiring has been poorly done the flow of current to ground or between the wires of opposite polarity may become quite large. Wires lying on pipes or on damp woodwork, crossed wires or live parts of apparatus mounted on wooden blocks, all tend to cut down the insulation resistance and increase the leak. The effects of poor insulation are: First, it represents a useless loss of current, and second, and more important, it means a possible cause of fire.

The simplest way to determine the insulation resistance of a circuit is by means of a voltmeter. In Figure 119 if a voltmeter of known resistance is connected between one side of the circuit and the ground and there is a ground on the other side of the circuit, say at X, current will flow from the positive wire through the voltmeter then through the ground at X to the negative side of the circuit. The voltmeter needle will indicate a certain reading which we will call V^1. If the voltmeter is now connected directly across the circuit we get the circuit voltage, which we call V. The two readings, V^1 and V, are to each other as the resistance of the voltmeter is to the combined resistance of the voltmeter and the ground at X, or, calling the resistance of the voltmeter R and the resistance of the ground at X r, we get $\frac{V^1}{V}=\frac{R}{R+r}$, or $r=R\frac{V-V^1}{V^1}$. As an example: On a certain system the voltage across the mains is 110, while with the volt-

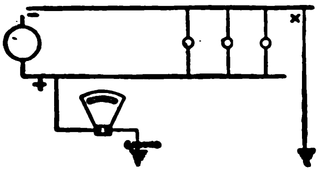


FIGURE 119.

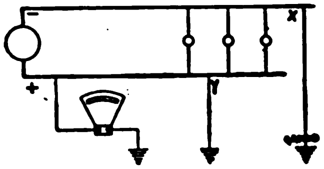


FIGURE 120.

meter connected as shown in Figure 119, we obtain a reading of 30. The resistance of the voltmeter is 10,500 ohms. Supplying the number in the formula, $r = 10{,}500 \times \frac{110-30}{30} = 28{,}000$ ohms as the resistance to ground of the negative side of the system. If the voltmeter is connected to ground from the other side, or — main, the resistance to ground of the + side can be obtained.

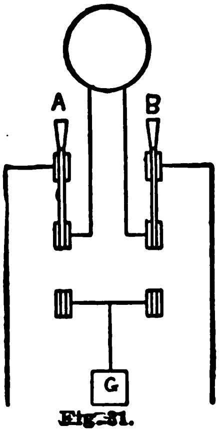


FIGURE 121.

If both sides of the system are grounded as at x and y, Figure 120, the voltmeter will be robbed of part of the current which would pass through it if Y were not in parallel with it. It will therefore not indicate correctly under such circumstances.

If, however, tests are frequently made and defects cleared up at once when noticed, it will seldom happen that two grounds occur on the system at the same time. An engineer or dynamo tender will soon learn what the insulation resistance of the plan in his charge should be and be governed accordingly.

A diagram of a direct current ground detector switch is shown in Figure 121. By throwing switch A down the — bus bar is connected to the ground through the voltmeter and by throwing switch B the + bar is connected to ground through the voltmeter. The ground wire should be run to a water or steam pipe (never to a gas pipe) or to some grounded part of the building. If no good ground is obtainable one may be made as described under 13 A.

8. Motors.

a. Must be thoroughly insulated from the ground wherever feasible. Wooden base-frames used for this purpose, and wooden floors which are depended upon for insulation where, for any reason, it is necessary to omit the base-frames, must be kept filled to prevent absorption of moisture, and must be kept clean and dry.

Where frame insulation is impracticable, the Inspection Department having jurisdiction may, in writing, permit its omission, in which case the frame must be permanently and effectively grounded.

A high-potential machine which, on account of great weight or for other reasons, cannot have its frame insulated, should be surrounded with an insulated platform. This may be made of wood, mounted on insulating supports and so arranged that a man must stand upon it in order to touch any part of the machine.

In case of a machine having an insulated frame, if there is trouble from static electricity due to belt friction, it should be overcome by placing near the belt a metallic comb connected to the earth, or by grounding the frame through a very high resistance of not less than 300,000 ohms.

Where motors with grounded frames are operated on systems where one side is either purposely or accidentally grounded there exists a certain difference of potential between the windings and the motor frame, this difference of potential depending on the part of the circuit considered. At some places in the winding it will be the full difference of potential at which the motor is operating and at other points practically nothing. Should the conductors accidentally come in contact or ground on the motor frame a short circuit would result, as the circuit would then be completed through the motor frame and ground. To obviate this the motor frame should be insulated from the ground. This may be done either by setting the motor on a wood floor or by the use of a base frame, as with generators. A base frame should always be used where possible, for when a motor is set directly on the floor it is often impossible to keep the space under it clean, and there is always a liability of the floor being damp or of nails in the floor passing through the woodwork into some grounded part of the building or metal piping. A properly constructed base frame will allow of easy cleaning of the space under the motor.

In the case of elevator or other motors where the shunt field is suddenly broken, a momentarily high voltage is induced in the field windings. If the frame of the motor is grounded this high voltage has a strong tendency to jump through the insulation of the wires to the metal work of the motor thus grounding the circuit.

b. Must be wired with the same precautions as required by rules in Class C for wires carrying a current of the same volume and potential.

Circuits for motors may be run in any of the ways described in Class C, either open on knobs or cleats, in moulding, concealed knob and tube work or in conduit, or any combination of these may be used. The conditions in each case will determine which is the best method to use. Where motors are placed some little distance from their switches and starting boxes, as in printing press work, conduit is often used for the wiring between the switch and starting box and the motor. This method provides very good mechanical protection for the wires and affords a safe way of running them.

The motor leads or branch circuits must be designed to carry a current at least twenty-five per cent. greater than that for which the motor is rated, in order to provide for the inevitable occasional overloading of the motor, and the increased current required in starting, without over-fusing the wires.

The use of voltages above 550 is rarely advisable or necessary, and will only be approved when every possible safeguard has been provided. Plans for such installations should be submitted to the Inspection Department having jurisdiction before any work on them is begun.

Good values to use for calculating the size of wire for branch conductors are given below. The question of loss of voltage is not taken into consideration here.

110 volts......9.3 amperes per horsepower
220 volts......4.6 amperes per horsepower
500 volts......2 amperes per horsepower

For mains supplying many motors it is not necessary to provide the twenty-five per cent. overload capacity, because it is not likely that all motors will start at the same time. If, however, any one motor has more than half the capacity of the whole installation, it is advisable to provide the overload capacity. For instance, if two motors, each of 50 amperes capacity, are fed over a line of 100 amperes capacity and one is started while the other is working at full load, they will overload that line twelve and one-half per cent.

For mains supplying many small motors the size should be chosen for the total load connected, using the following values:

110 volts.....7.5 amperes per horsepower
220 volts.....3.75 amperes per horsepower
500 volts.....1.65 amperes per horsepower

Where there are a number of 110-volt motors installed on the Edison 3-wire system, providing the load is evenly balanced between the two sides, the mains may be figured as though the motors were operating at 220 volts. The reason for this will be easily seen when it is remembered that two 110-volt motors operating in series on 220 volts (as they do on the Edison 3-wire system) take only one-half the current they would if operated on a straight 2-wire 110-volt system.

c. Each motor and resistance box must be protected by a cut-out and controlled by a switch (see No. 17 *a*), said switch plainly indicating whether on or off. With motors of one-fourth horsepower or less, on circuits where the voltage does not exceed 300, No. 21 *d* must be complied with, and single pole switches may be used as allowed in No. 22 *c*. The switch and rheostat must be located within sight of the motor, except in cases where special permission to locate them elsewhere is given, in writing, by the Inspection Department having jurisdiction.

Where the circuit-breaking device on the motor-starting rheostat disconnects all wires of the circuit, the switch called for in this section may be omitted.

Overload-release devices on motor-starting rheostats will not be considered to take the place of the cut-out required by this section if they are inoperative during the starting of the motor.

The switch is necessary for entirely disconnecting the motor when not in use, and the cut-out to protect the motor from excessive currents due to accidents or careless handling when starting. An automatic circuit-breaker, disconnecting all wires of the circuit may, however, serve as both switch and cut-out.

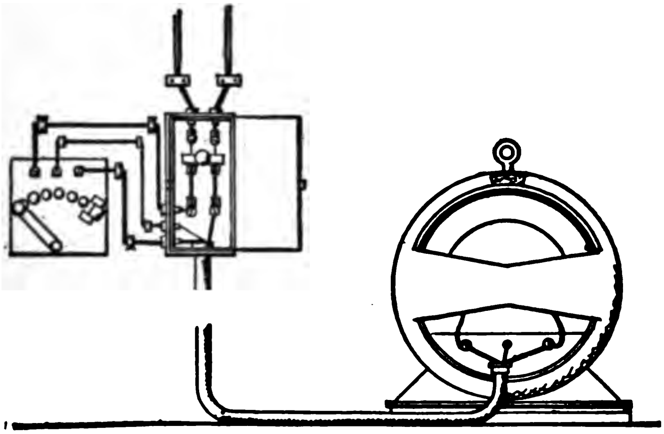


FIGURE 122.

For the larger size motors a cut-out must be installed for each motor, but with motors of ¼ horse power or less, where the voltage does not exceed 300, a cut-out need be installed for every 660 watts only. This allows about 5⅛ horsepower motors, 3 1/6 horsepower motors or 2¼ horsepower motors on one cut-out. Every motor, whether large or small must be controlled by a switch which will indicate whether the current is on or off. This is required to reduce the liability of a motor being accidentally left in circuit, which might result in serious trouble. Figure 122 shows a complete motor installation as usually arranged.

As a general rule fused knife switches are used for the larger motors, while with the smaller motors cut-out blocks and indicating snap switches are often used. If the motor is ¼ horsepower or less, and operated on a circuit where the voltage does not exceed 300, a single pole switch may be used. For all motors over ¼ horsepower, and for all motors operated on voltages over 300, double pole switches must be used. The object of locating the switch and starting box within sight of the motor is that, should any trouble occur when the motor is being started, such as a short circuit or overload, it will be immediately noticed and the current shut off. If the conditions are such that it is necessary to locate the motor out of sight of the switch and starting box the motor should be located in a safe place, away from inflammable material. A special permit should be obtained from the inspection department having jurisdiction in order that the exact conditions may be noted.

d. Must have their rheostats or starting boxes located so as to conform to the requirements of No. 4.

The use of circuit breakers with motors is recommended, and may be required by the Inspection Department having jurisdiction.

To be safe a rheostat should have as great a carrying capacity as the motor itself, or else the arm should have a strong spring-throw attachment, so arranged that it cannot remain at any intermediate position unless purposely held there. Specifications governing the construction of rheostats are given in No. 60.

Starting rheostats and auto-starters should be treated about the same as knife-switches, and in all wet, dusty or linty places should be enclosed in dust-tight, fireproof cabinets. If a special motor room is provided, the starting apparatus and safety devices should be included within it. Where there is any liability of short circuit across their exposed live parts being caused by accidental contacts, they should either be enclosed in cabinets, or else a railing should be erected around them to keep unauthorized persons away from their immediate vicinity.

In some cities the local rules allow the starting box or rheostat to be mounted on asbestos board, in which case it must be mounted out from the wall on porcelain knobs so that there will be at least one inch air space between the wall and the current-carrying parts. If the starting box or rheostat is to be mounted on a wall or other support where the frame would be grounded, it may be attached to a wood support and the wood support then independently attached to the wall. The best construction is to use slate or marble. If slate or marble is used it must be a continuous piece which will entirely cover the space back of the rheostat and the frame of the rheostat should be screwed to the slate or marble and the slate or marble then independently screwed to the wall, never using the same screw for attaching both.

A starting box is a device for limiting the current strength during the starting of the motor by inserting a resistance in series with the armature. The ohmic resistance of the armature of a shunt or compound wound motor is ordinarily very small. When such a motor is at rest and the current thrown directly on, the full voltage is thrown across the small resistance of the armature.

Consider for a moment the case of a 1 horsepower 110 volt motor having an armature resistance of say 2 ohms, and taking, when running normally, 8 amperes. Suppose the current were thrown on without the use of a starting box. According to Ohm's law the current through the armature would be 110/2=55 amperes. The results, were 55 amperes sent through the armature, can easily be imagined. Now, suppose a resistance of 8 ohms were inserted in series with the armature when starting. In this case 110/10=11 amperes only would have to pass through the armature and this the armature can easily stand. As the motor begins to revolve a counter electromotive force is generated which opposes the inrush of current. This counter electro-motive force increases until the motor reaches full speed and takes its normal current.

In the example given above at the first step of the starting box there will be a current of 11 amperes flowing through a resistance of 8 ohms and the power consumed will be equal to I^2 R, or 968 watts, which are lost in heat produced in the resistance wire. As this amounts to more than one horsepower thrown off in heat the advisability of mounting the rheostat away from inflammable material and of properly ventilating it can readily be seen.

Fig. 123 shows an illustration of an automatic starting box, and a diagram of the connections to a motor circuit. It will be seen that the resistance coils are in series with the armature circuit. As the arm A is moved to the right, resistance is gradually cut out of the armature circuit until the arm reaches the last point, where it is automatically held in position by means of the small magnet m, which is connected in series with the field circuit. By tracing out the circuits it will be found that the field connection is made on the first point of the rheostat, so that when the arm A is in the off position there is no current passing through the field coils. It will also be noticed that the last contact upon which the arm rests when off is dead. If the supply current for any reason fails, current will cease to flow around the coils of the magnet M and it will become demagnetized, thus allowing the arm A to fly back to the off position. This overcomes the possibility of the main current being momentarily shut off and then thrown on when all the resistance is out of the armature circuit. This device is known as no-voltage release.

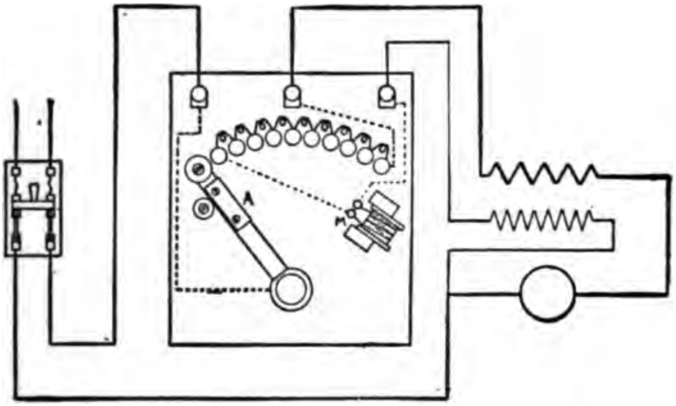


FIGURE 123.

Another device known as the overload release, is shown in Figure 124 with a diagram of the connections. The winding of the magnet M^1 carries the main current. When the current exceeds a certain amount (which can be regulated by a small nut) the armature below the magnet will be attracted, thus short circuiting the coil M and allowing the arm to fly back and shut off the current to the motor. This device cannot be considered to take the place of the reglar cut-outs, as it is not operative during the starting of the motor. It can only operate after the arm A is held in position by the magnet M.

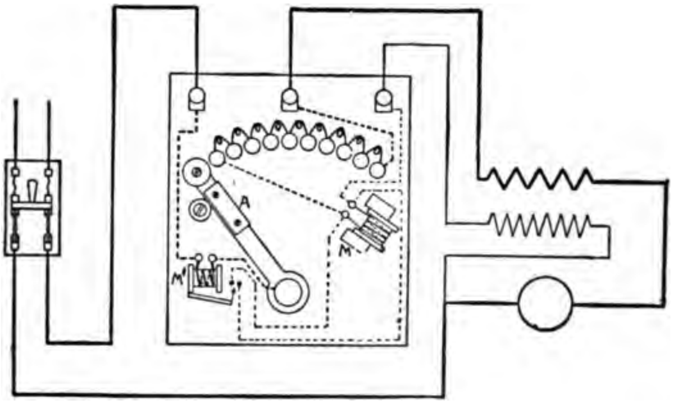


FIGURE 124.

Starting boxes are made in different designs to meet the requirements of the various classes of work on which they are used. Figure 125 shows a large automatic starting box where the resistance is cut out by the action of the solenoid S, which draws up the movable arm. When solenoids are used for this purpose it is often advisable to arrange the connections so that when the movable arm has been raised to the highest and last point a resistance will be inserted in series with the solenoid to cut down the current and reduce the heating in the coil, as less current is required to hold the arm in place than to move it over the contacts. Incandescent lamps are often used for this purpose and must be installed as in 4, Class A.

A speed controller differs from a starting box mainly in the size of wire used as resistance. The resistance coils of a starting box are wound with comparatively small wire connected in circuit for a short time only, generally from ten to twenty seconds, while in a speed controller the wire must be of sufficient size to carry the current as long as the motor is running. Another difference between the starting box and speed controller is the automatic coil, (Fig. 123) M, which in the speed con-

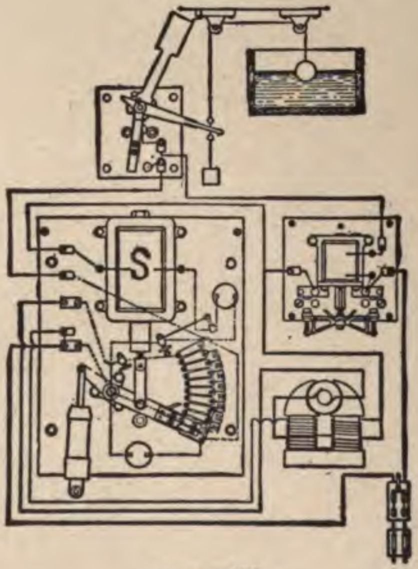


FIGURE 125.

troller is arranged to hold the arm A in any position in which it may be placed. This is accomplished in some types of speed controllers by a lever attached to an armature, which is attracted by the magnet M, the other end of the lever fitting into a series of indentations on lower part of movable arm.

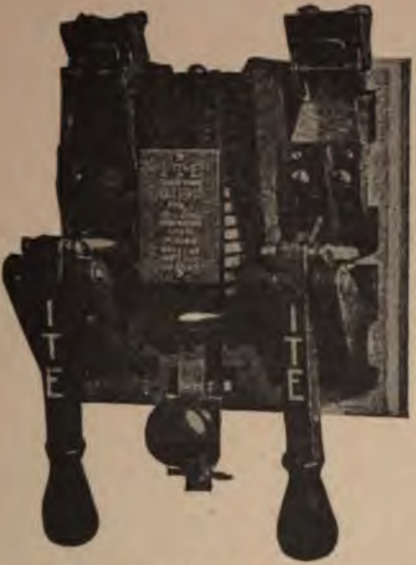


FIGURE 126.

While the underwriter's rules do not require a speed controller to be automatic, still it is good practice to make them so, as the same principles apply to the starting of a motor with a speed controller as with a starting box.

Figure 126 shows a circuit breaker which is operative during the starting of the motor, and can be used to take the place of the switch required.

As the arm of a starting box or speed controller is moved from one contact to another, more or less sparking results, and as has already been stated, considerable heat is developed in the coils. A rheostat should never be located in a room where either inflammable gases or dust exist. If a starting box is to be located in a room where considerable lint is apt to gather, or if the room is unusually damp, the starting box should be mounted in a dust-tight fire-proof box, which should be kept closed at all times, except when starting the motor. If the enclosing box is rather large, sufficient ventilation of the coils will be obtained while the motor is being started and the door open. A speed controller should never be mounted in an enclosure unless the same is arranged to give a thorough ventilation to the outside air, as heat is constantly being generated in the coils of the rheostat, and this heat must be dissipated. A speed controller should never be located where dust or lint is apt to gather on it. If it is necessary to use one on a motor located in such a place, it should be mounted outside the room.

In metal working establishments or in any place where there is a liability of the contacts on the switches or the starting boxes being short-circuited, they should be enclosed or suitably protected.

e. Must not be run in series-multiple or multiple-series, except on constant-potential systems, and then only by special permission of the Inspection Department having jurisdiction.

Figure 127 shows a series-multiple, and Figure 128 a multiple-series system of wiring.

f. Must be covered with a waterproof cover when not in use, and, if deemed necessary by the Inspection Department having jurisdiction, must be enclosed in an approved case.

From the nature of the question the decision as to what is an approved case must be left to the Inspection Department having jurisdiction to determine in each instance.

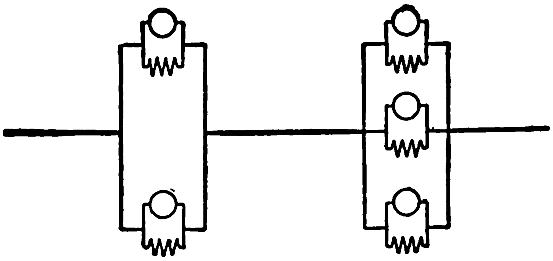


FIGURE 127.

When it is necessary to locate a motor in the vicinity of combustibles or in wet or very dusty or dirty places, it is generally advisable to surround it with a suitable enclosure.

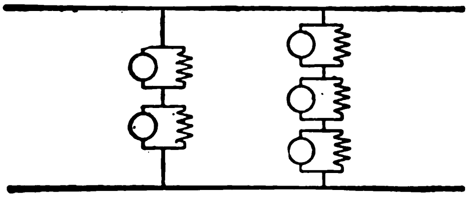


FIGURE 128.

The sides of such enclosure should preferably be made largely of glass, so that the motor may be always plainly visible. This lessens the chance of its being neglected, and allows any derangement to be at once noticed.

Under certain conditions it is found necessary to enclose motors in dust-tight enclosures. The practice of building a small box which fits entirely around the motor, enclosing the pulley and provided with slots through which the belt passes, is very unsatisfactory. While this construction prevents considerable dust from settling on and around the motor, still a great deal will be carried in by the belt. If the box is so made that it fits tightly around the shaft between the pulley and the motor frame and is otherwise well constructed, most of the dust and dirt can be kept out. As the efficient working of the motor requires that it be kept as cool as possible, the box should afford sufficient ventilation. This may be obtained by making the box somewhat larger than the motor, thus allowing the heat to radiate from the sides, or the boxes should be ventilated to the outside air.

A number of motors are so constructed that, by means of hand plates, they can be entirely enclosed. When they are so enclosed their efficiency and capacities are somewhat reduced, but cases are sometimes found where the conditions require motors of this kind to be used.

In places where there is considerable dust flying about in the air, and where the dust is not readily combustible, a fine gauze can be used to close the hand holes. This gauze will allow ventilation, but will prevent the dirt from gathering inside the motor. The alternating induction motors, which are operated without brushes or collector rings, can be used in almost any location, as there is no sparking.

g. Must, when combined with ceiling fans, be hung from insulated hooks, or else there must be an insulator interposed between the motor and its support.

Ceiling fans are generally provided with an insulating knob on which the fan hangs. If this is not provided, a simple knob break can be used, or the fan can be suspended from a hook screwed into a hardwood block, provided the hook does not pass through the block into the plaster, the block being separately supported from the ceiling.

h. Must each be provided with a name-plate, giving the maker's name, the capacity in volts and amperes, and the normal speed in revolutions per minute.

9. Railway Power Plants.

a. Each feed wire before it leaves the station must be equipped with an approved automatic circuit-breaker (see No. 52) or other device, which will immediately cut off the current in case of an accidental ground. This device must be mounted on a fireproof base, and in full view and reach of the attendant.

10. Storage or Primary Batteries.

a. When current for light and power is taken from primary or secondary batteries, the same general regulations must be observed as apply to similar apparatus fed from dynamo generators developing the same difference of potential.

b. Storage battery rooms must be thoroughly ventilated.

c. Special attention is directed to the rules for wiring in rooms where acid fumes exist (see No. 24, *i* to *k*).

d. All secondary batteries must be mounted on non-absorptive, non-combustible insulators, such as glass or thoroughly vitrified and glazed porcelain.

e. The use of any metal liable to corrosion must be avoided in cell connections of secondary batteries.

Rubber-covered wire run on glass knobs should be used for wiring storage battery rooms. The knobs should be of such size as to keep the wire at least one inch from the surface wired over, and they should be separated 2½ inches for voltage up to 300, and 4 inches for voltages over 300. Waterproof sockets hung from stranded rubber covered wire and properly supported independently of the joints should be used; these lights to be controlled by a switch placed outside of battery room. All joints after being properly soldered and taped with both rubber and friction tape should be painted with some good insulating compound. This tends to keep all acid fumes away from the wire.

11. Transformers.

(For construction rules, see No. 62.)
(See also Nos. 13, 13 a, 36.)

a. In central or sub-stations the transformers must be so placed that smoke from the burning out of the coils or the boiling over of the oil (where oil filled cases are used) could do no harm.

If the insulation in a transformer breaks down, considerable heat is likely to be developed. This would cause a dense smoke, which might be mistaken for a fire and result in water being thrown into the building, and a heavy loss thereby entailed. Moreover, with oil cooled transformers, especially if the cases are filled too full, the oil may become ignited and boil over, producing a very stubborn fire.

NOTICE—DO NOT FAIL TO SEE WHETHER ANY RULE OR ORDINANCE OF YOUR CITY CONFLICTS WITH THESE RULES.

Class B.

OUTSIDE WORK.

All Systems and Voltages.

12. Wires.

a. Service wires must have an approved rubber insulating covering (see No. 41). Line wires, other than services, must have an approved weatherproof or rubber insulating covering (see Nos. 41 and 44). All tie wires must have an insulation equal to that of the conductors they confine.

In risks having private generating plants, the yard wires running from building to building are not generally considered as service wires, so that rubber insulation would not be required.

By service wires are meant those wires which enter the building. It is customary to run the rubber-covered wire from the service switch and cutout inside of building through the outer walls, and to leave but a few feet of wire to which the line wires can later be spliced. This is illustrated in Figure 129, which shows how wires are run from pole to building.

b. Must be so placed that moisture cannot form a cross connection beteen them, not less than a foot apart, and not in contact with any substance other than their insulating supports. Wooden blocks to which insulators are attached must be covered over their entire surface with at least two coats of waterproof paint.

c. Must be at least 7 feet above the highest point of flat roofs, and at least one foot above the ridge of pitched roofs over which they pass or to which they are attached.

Roof structures are frequently found which are too low or much too light for the work, or which have been carelessly put up. A structure which is to hold the wires a proper distance above the roof in all kinds of weather must not only be of sufficient height, but must be substantially constructed of strong material.

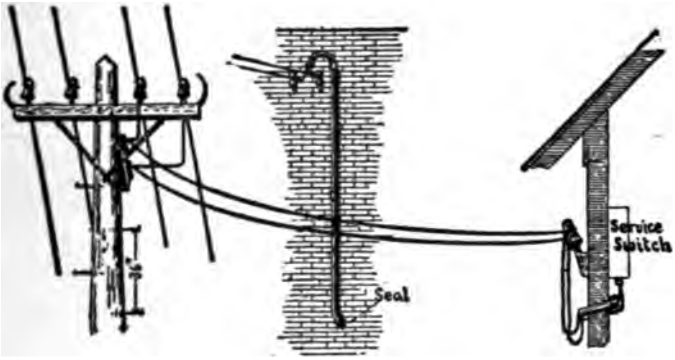


FIGURE 129.

It is well to avoid fastening wires perpendicular above one another, as in winter icicles may form which extend from the top to the lower wire, and the moisture on these will often cause much trouble. The rule requires that wires be 7 feet above flat roofs, and roof structures must, therefore, be made high enough to allow for sag. In moderately long runs 2 or 3 feet will be sufficient. For long runs, see following table, taken from construction rules of Commonwealth Eectric Company of Chicago:

The tension on wires should be such that the sag of a span of 125 feet will not exceed the amounts shown.

Temperature, F.	10	20	30	40	50	60	70	80	90
Sag, feet	6	8	8	10	10	12	12	14	14

This table will also be useful to consult when running wires over house tops to which they are not attached, as it shows the variation in sag due to different temperatures. Wires should be so run that even at the highest temperature they will still clear the buildings. Allowance should also be made for the gradual elongation of the wire due to its own weight, giving way of supports or sleet that may at times weigh it down.

d. Must be protected by dead insulated guard irons or wires from possibility of contact with other conducting wires or substances to which current may leak. Special precautions of this kind must be taken where sharp angles occur, or where any wires might possibly come in contact with electric light or power wires.

Crosses, when unavoidable, should be made as nearly at right angles as possible.

These guard wires are run parallel to and above the lower set of wires. Their object is to prevent the upper crossing wires, should they break, from coming in contact with the lower. A separate set of cross arms must be placed on the lower poles or above the lower wires to which the guard wires must be fastened. In Figure 130 1 and 2 show break insulators that may be used to electrically disconnect guard wires.

e. Must be provided with petticoat insulators of glass or porcelain. Porcelain knobs or cleats and rubber hooks will not be approved.

f. Must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered, to insure preservation, and covered with an insulation equal to that on the conductors.

All joints must be soldered, even if made with some form of patent splicing device. This ruling applies to joints and splices in all classes of wiring covered by these rules.

In Figure 130 single and double petticoat insulators are shown. It is very often convenient to fasten such insulators upside down or horizontally, but this should never be done, as they will then fill with water or dirt and their insulating qualities be destroyed.

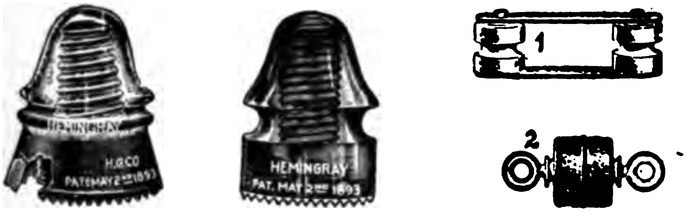


FIGURE 130.

g. Must, where they enter buildings, have drip loops outside, and the holes through which the conductors pass must be bushed with non-combustible, non-absorptive insulating tubes slanting upward toward the inside.

h. Telegraph, telephone and similar wires must not be placed on the same cross-arm with electric light or power wires, and when placed on the same pole with such wires the distance between the two inside pins of each cross-arm must not be less than 26 inches.

i. The metallic sheaths to cables must be permanently and effectively connected to earth.

The telephone or telegraph wires are sometimes placed above the power wires, and it very often becomes necessary for a lineman to pass through the lower wires to get at the upper. Great care is necessary to avoid coming in contact with high tension power wires while handling the telephone wires.

Poles should not be set more than 125 feet apart; 100 or 110 feet is good practice. For small wires poles with 6-inch tops are often used, but for heavier wires 7-inch tops are advisable. The tops of pole should be pointed, so as to shed water, and the whole pole be well painted. Steps should be placed so that the distance between any two steps on the same side is not over 36 inches; these steps should be all the same distance apart, and should not extend nearer than 8 feet to the ground. All gains cut into poles should be painted before cross-arms are placed in them. Such places are more likely to hold moisture and rot than exposed parts. Wherever feed wires end or sharp angles occur, double cross-arms should be used, fastened on opposite sides of pole and bolted together.

All bolts, lag screws, etc., should be galvanized. Poles should be set at least as far into the ground as shown in the following table:

Length of pole.	Depth in ground.
35 feet	5½ feet
40 "	6 "
45 "	6 "
50 "	6½ "
55 "	7 "
60 "	8 "

The holes should be large enough to admit of thorough tamping on all sides of bottom of hole. If the tamping at bottom of hole is not well done, the pole will always be shaky, no matter how much tamping may be done at the top. If the ground is soft, the pole may be set in cement, or short pieces of planking fastened to it at right angles underground. At the end of line or where sharp bends occur, strong galvanized guy cables fastened to poles six or eight feet long, buried underground, should be used.

Trolley Wires.

j. Must not be smaller than No. 0 B. & S. Gauge copper or No. 4 B. & S. Gauge silicon bronze, and must readily stand the strain put upon them when in use.

k. Must have a double insulation from the ground. In wooden pole construction the pole will be considered as one insulation.

l. Must be capable of being disconnected at the power plant, or of being divided into sections, so that, in case of fire on the railway route, the current may be shut off from the particular section and not interfere with the work of the firemen. This rule also applies to feeders.

m. Must be safely protected against accidental contact where crossed by other conductors.

Guard wires should be insulated from the ground and should be electrically disconnected in sections of not more than 300 feet in length.

Ground Return Wires.

n. For the diminution of electrolytic corrosion of underground metal work, ground return wires must be so arranged that the difference of potential between the grounded dynamo terminal and any point on the return circuit will not exceed twenty-five volts.

It is suggested that the positive pole of the dynamo be connected to the trolley line, and that whenever pipes or other underground metal work are found to be electrically positive to the rails or surrounding earth, that they be connected by conductors arranged so as to prevent as far as possible current flow from the pipes into the ground.

12 A. Constant-Potential Pole Lines, Over 5,000 Volts.

(Overhead lines of this class unless properly arranged may increase the fire loss from the following causes:—

Accidental crosses between such lines and low-potential lines may allow the high-voltage current to enter buildings over a large section of adjoining country. Moreover, such high voltage lines, if carried close to buildings, hamper the work of firemen in case of fire in the building. The object of these rules is so to direct this class of construction that no increase in fire hazard will result, while at the same time care has been taken to avoid restrictions which would unreasonably impede progress in electrical development.

It is fully understood that it is impossible to frame rules which will cover all conceivable cases that may arise in construction work of such an extended and varied nature, and it is advised that the Inspection Department having jurisdiction be freely consulted as to any modification of the rules in particular cases.)

a. Every reasonable precaution must be taken in arranging routes so as to avoid exposure to contacts with other electric circuits. On existing lines, where there is a liability to contact, the route should be changed by mutual agreement between the parties in interest wherever possible.

b. Such lines should not approach other pole lines nearer than a distance equal to the height of the taller pole line, and such lines should not be on the same poles with other wires, except that signaling wires used by the Company operating the high-pressure system, and which do not enter property other than that owned or occupied by such Company may be carried over the same poles.

c. Where such lines must necessarily be carried nearer to other pole lines than is specified in Section *b* above, or where they must necessarily be carried on the same poles with other wires, extra precautions to reduce the liability of a breakdown to a minimum must be taken, such as the use of wires of ample mechanical strength, widely spaced cross-arms, short spans, double or extra heavy cross-arms, extra heavy pins, insulators and poles thoroughly supported. If carried on the same poles with other wires, the high-pressure wires must be carried at least three feet above the other wires.

d. Where such lines cross other lines, the poles of both lines must be of heavy and substantial construction.

Whenever it is feasible, end-insulator guards should be placed on the cross-arms of the upper line. If the high-pressure wires cross below the other line, the wires of the upper line should be dead-ended at each end of the span to double-grooved, or to standard transposition insulators, and the line completed by loops.

One of the following forms of construction must then be adopted:

1. The height and length of the cross-over span may be made such that the shortest distance between the lower cross-arms of the upper line and any wire of the lower line will be greater than the length of the cross-over span, so that a wire breaking near one of the upper pins would not be long enough to reach any wire of the lower

line. The high-pressure wires should preferably be above the other wires.

2. A joint pole may be erected at the crossing point, high-pressure wires being supported on this pole at least three feet above the other wires. Mechanical guards or supports must then be provided, so that in case of the breaking of any upper wire, it will be impossible for it to come into contact with any of the lower wires.

Such liability of contact may be prevented by the use of suspension wires, similar to those employed for suspending aerial telephone cables, which will prevent the high-pressure wires from falling in case they break. The suspension wires should be supported on high-potential insulators, should have ample mechanical strength, and should be carried over the high-pressure wires for one span on each side of the joint pole, or where suspension wires are not desired guard wires may be carried above and below the lower wires for one span on each side of the joint pole, and so spread that a falling high-pressure wire would be held out of contact with the lower wires.

Such guard wires should be supported on high-potential insulators or should be grounded. When grounded, they must be of such size, and so connected and earthed, that they can surely carry to ground any current which may be delivered by any of the high-pressure wires. Further, the construction must be such that the guard wires will not be destroyed by any arcing at the point of contact likely to occur under the conditions existing.

3. Whenever neither of the above methods is feasible, a screen of wires should be interposed between the lines at the cross-over. This screen should be supported on high tension insulators or grounded and should be of such construction and strength as to prevent the upper wires from coming into contact with the lower ones.

If the screen is grounded each wire of the screen must be of such size and so connected and earthed that it can surely carry to ground any current which may be delivered by any of the high pressure wires. Further, the construction must be such that the wires of screen will not be destroyed by any arcing at the point of contact likely to occur under the conditions existing.

e. When it is necessary to carry such lines near buildings, they must be at such height and distance from the building as not to interfere with firemen in event of fire: therefore, if within 25 feet of a building, they must be carried at a height not less than that of the front cornice, and the height must be greater than that of the cornice, as the wires come nearer to the building, in accordance with the following table:—

Distance of wire from building. Feet.	Elevation of wire above cornice of building. Feet.
25	0
20	2
15	4
10	6
5	8
2½	9

It is evident that where the roof of the building continues nearly in line with the walls, as in Mansard roofs, the height and distance of the line must be reckoned from some part of the roof instead of from the cornice.

13. Transformers.

(For construction rules, see No. 62.)
(See also Nos. 11, 13 A and 36.)

Where transformers are to be connected to high-voltage circuits, it is necessary in many cases, for best protection to life and property, that the secondary system be permanently grounded, and provision should be made for it when the transformers are built.

a. Must not be placed inside of any building excepting central stations, unless by special permission of the Inspection Department having jurisdiction.

An outside location is always preferable; first, because it keeps the high-voltage primary wires entirely out of the building, and second, for the reasons given in the note to No. 11 a.

b. Must not be attached to the outside walls of buildings, unless separated therefrom by substantial supports.

The alternating current transformer consists of an iron core upon which wires of two distinct electrical circuits are wound. One of these is known as the primary circuit, and in it the high pressure currents coming direct from the dynamo circulate. The other is known as the secondary circuit, and in it the low pressure currents used inside of buildings circulate. These two circuits are wound generally one over the other, and are very close together. The pressure used in the primary coil is from 1,000 to 5,000 volts, while in the secondary it is reduced usually to 110 or 220.

It quite frequently happens that the insulation between the two windings breaks down and thus the high pressure is accidentally brought into buildings. Under such circumstances should any one touch any live part of the installation while touching also grounded parts of the building death would very likely result. Also, should there be a weak spot in the insulation, it is quite likely the high pressure would pierce it at that point with a possible result of a fire. Many deaths and fires have been caused in this way. If such lines are connected to ground the chances for harm are very much lessened, for the current will never take the path of high resistance through a man's body, while a direct path through a low resistance wire is open to it.

It must not be supposed that grounding one side of an electric light system is not often followed by serious consequences, for under such circumstances a ground coming on any other part of the system will cause a short circuit at once. The grounding in these cases is to be looked upon as the lesser of two evils rather than as an advantage. With alternating currents, the chances of possible damage from grounding are much less than with direct currents, because each transformer with its small group of lamps is a system by itself and not affected by grounds on other transformers. Thus a 5,000 light alternating current installation would consist of from 25 to 50 separate systems, each independent of defects on the rest, while in a continuous current installation, a ground on the most remote branch circuit would in conjunction with a ground on the opposite pole of any other part of the system form a short circuit.

Methods of grounding secondary wires of alternating current transformers are shown in Figure 131, taken from an instruction book issued by the Commonwealth Electric Company of Chicago.

In connection with 3-wire systems, grounding of the neutral wire can do little harm, because ordinarily the neutral wire seldom carries much current, and that current is apt to vary in direction so that the electrolytic effect will be on the whole quite negligible.

There is, of course, the hazard brought about by the fact that a ground coming on one of the outside wires will immediately form a short-circuit in connection with the ground on the neutral.

In connection with 3-wire systems, however, it is of the greatest importance (as more fully explained further on) that the neutral wire remain intact, and it being thoroughly grounded at all available outside places will help to keep it so.

13 A. Grounding Low-Potential Circuits.

The grounding of low-potential circuits under the following regulations is only allowed when such circuits are so arranged that under normal conditions of service there will be no passage of current over the ground wire.

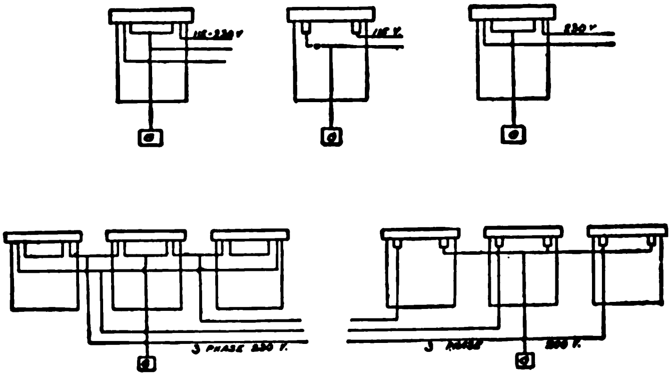


FIGURE 131.

Direct-Current 3-Wire System.

a. Neutral wire may be grounded, and when grounded the following rules must be complied with:—

1. Must be grounded at the Central Station on a metal plate buried in coke beneath permanent moisture level and also through all available underground water and gas-pipe systems.

2. In underground systems the neutral wire must also be grounded at each distributing box through the box.

3. In overhead systems the neutral wire must be grounded every 500 feet as provided in Sections *c, e, f* and *g*.

Inspection Department having jurisdiction may require grounding if they deem it necessary.

Two-wire direct-current systems having no accessible neutral point are not to be grounded.

Alternating-Current Secondary Systems.

b. Transformer secondaries of distributing systems should preferably be grounded, and when grounded, the following rules must be complied with:—

1. The grounding must be made at the neutral point or wire, whenever a neutral point or wire is accessible.

2. When no neutral point or wire is accessible, one side of the secondary circuit may be grounded, provided the maximum difference of potential between the grounded point and any other point in the circuit does not exceed 250 volts.

3. The ground connection must be at the transformer as provided in sections *d, e, f, g,* and when transformers feed systems with a neutral wire, the neutral wire must also be grounded at least every 250 feet for overhead systems, and every 500 feet for underground systems.

Inspection Departments having jurisdiction may require grounding if they deem it necessary.

Ground Connection.

c. The ground wire in direct-current 3-wire systems must not at Central Stations be smaller than the neutral wire and not smaller than No. 6 B. & S. Gauge elsewhere.

d. The ground wire in alternating-current systems must never be less than No. 6 B. & S. Gauge, and must always have equal carrying capacity to the secondary lead of the transformer, or the combined leads where transformers are connected in parallel.

On three phase systems, the ground wire must have a carrying capacity equal to that of any one of the three mains.

e. The ground wire must be kept outside of buildings, but may be directly attached to the building or pole. The wire must be carried in as nearly a straight line as possible, and kinks, coils and sharp bends must be avoided.

f. The ground connection for Central Stations, transformer substations, and banks of transformers must be made through metal plates buried in coke below permanent moisture level, and connection should also be made to all available underground piping systems including the lead sheath of underground cables.

g. For individual transformers and building services the ground connection may be made as in Section *f*, or may be made to water or other piping systems running into the buildings. This connection may be made by carrying the ground wire into the cellar and connecting on the street side of meters, main cocks, etc., but connection must never be made to any lead pipes which form part of gas services.

In connecting a ground wire to a piping system, the wire should, if possible, be soldered into a brass plug and the plug forcibly screwed into a pipe-fitting or, where the pipes are cast iron, into a hole tapped into the pipe itself. For large stations, where connecting to underground pipes with bell and spigot joints, it is well to connect to several lengths, as the pipe joints may be of rather high resistance. Where plugs cannot be used, the surface of the pipe may be filed or scraped bright, the wire wound around it, and a strong clamp put over the wire and firmly bolted together.

Where ground plates are used, a No. 16 Stubbs' Gauge copper plate, about three by six feet in size, with about two feet of crushed coke or charcoal, about pea size, both under and over it, would make a ground of sufficient capacity for a moderate-sized station, and would probably answer for the ordinary substation or bank of transformers. For a large central station, a plate with considerably more area might be necessary, depending upon the other underground connections available. The ground wire should be riveted to the plate in a number of places, and soldered for its whole length. Perhaps even better than a copper plate is a cast-iron plate with projecting forks, the idea of the fork being to distribute the connection to the ground over a fairly broad area, and to give a large surface contact. The ground wire can probably best be connected to such a cast-iron plate by soldering it into brass plugs screwed into holes tapped in the plate. In all cases, the joint between the plate and the ground wire should be thoroughly protected against corrosion by painting it with waterproof paint or some equivalent.

NOTE.—DO NOT FAIL TO SEE WHETHER ANY RULE OF ORDINANCE OF YOUR CITY CONFLICTS WITH THESE RULES.

CLASS C.

INSIDE WORK.

All Systems and Voltages.

GENERAL RULES.

14. Wires.

(For special rules, see Nos. 18, 24, 35, 38 and 39.)

a. Must not be of smaller size than No. 14 B. & S. Gauge, except as allowed under Nos. 24 *v* and 45*b*.

The exceptions being wires used inside of fixtures and flexible cord used to suspend individual electric lights. For general purposes a wire smaller than No. 14 is too easily broken, either through a sharp kink, or by drawing too tight with tie wires. To avoid trouble from kinks or sharp bends, wires smaller than 14 should preferably be stranded.

b. Tie wires must have an insulation equal to that of the conductors they confine.

This is considered necessary, because very often the tie wire cuts through the insulation of the wire it confines, and if the tie wire should come in contact with other than its insulating support, there would still be good insulation. In Figure 132, (1) and (2) illustrate the method of tieing usually employed with small wires on insulators, (4) shows a method employed with larger wires.

This is also especially useful, because slack can be taken up if the tie wire is arranged to draw the main wire about half way around the insulator, (6) shows a knot tied into the wire, as is usual where the end of the wire connects into cut-outs or switches. At (5) insulators are arranged to hold large wires. It is not advisable to tie large wires to insulators, as the weight of the wire will soon cause it to cut through the insulation. Cleats, such as shown at (8) and (9), are preferable.

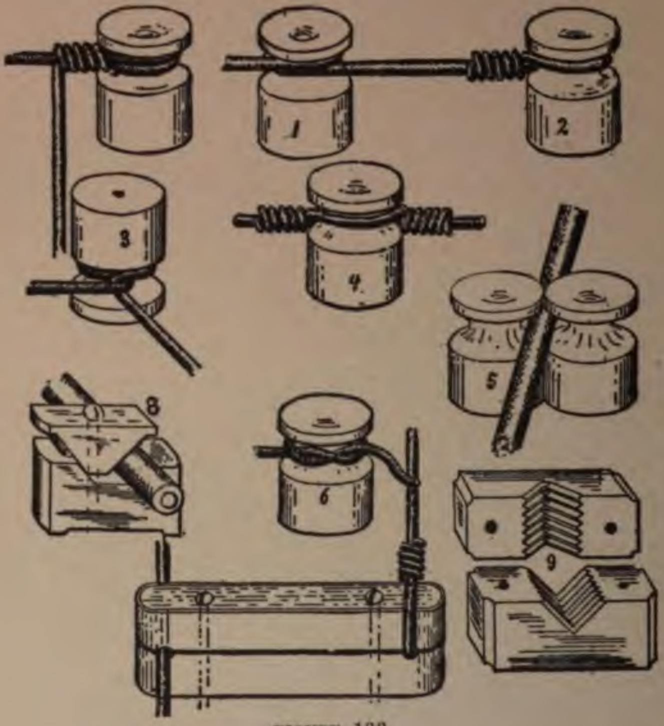


FIGURE 132.

c. Must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered to insure preservation and covered with an insulation equal to that on the conductors.

Stranded wires must be soldered before being fastened under clamps or binding screws, and whether stranded or solid, when they have a conductivity greater than that of No. 8 B. & S. Gauge they must be soldered into lugs for all terminal connections.

All joints must be soldered, even if made with some form of patent splicing device. This ruling applies to joints and splices in all classes of wiring covered by these rules.

At the left on top of Fig. 133 is shown the well-known Western Union joint. Before joining wires they should be thoroughly cleaned by scraping with the back of a knife or sand or emery paper. The insulation should be removed, as indicated at *b*, if it is cut into as at *a*, it is very likely that the wire will be nicked and will be likely to break at that point. It is also more difficult to tape a joint properly if the rubber has been cut in this way than it is with the rubber cut as at *b*. After the joint has been made it is covered with soldering fluid, a formula for which is given below. In lieu of this there are soldering sticks and salts, already prepared, on the market.

The following formula for soldering fluid is suggested:—

Saturated solution of zinc cloride...	5 parts
Alcohol	4 parts
Glycerine	1 part

The joint having been thoroughly covered with one of these preparations is next heated with a gasoline or alcohol torch and a small piece of solder allowed to melt

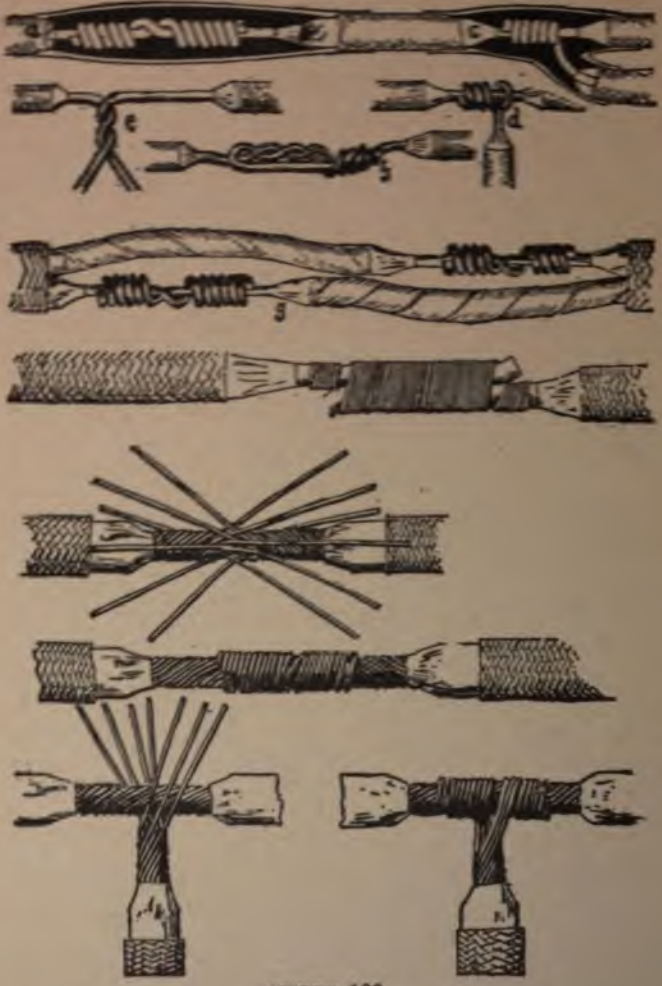


FIGURE 133.

on it near the center. It is well to avoid heating too much at the ends of the joint, as it weakens the wire. After the joint is cool, wipe off all moisture and cover with layers of rubber tape, enough, at least, so that it is equal in thickness to the rubber insulation on the wire used, as shown at *a* and *b*. This rubber tape is then covered with friction tape to keep it in place. Before taping joints the outer braid of the wire should be carefully skinned back. If any of the cotton threads of which it consists were to be left in contact with the bare wire, they would, then moist, form a leak, which might prove troublesome. If joints are exposed to the weather it will be well to paint them over with some insulating paint to keep the friction tape in place, as it will otherwise soon work loose when it becomes dry.

At *c* and *d* tap joints are shown. The method shown at *d* is preferable, because the wire cannot easily work loose. The method of joining shown at *e* is useful when, for instance, two wires, each of which is fastened to an insulator, are to be joined. The wires can be drawn very tight in this way. This sort of joint is very common in fixture work, and should be finished off as at *f*.

Twin wires other than flexible cord are allowed only in metal conduits, and joints in them should be made only within the junction boxes. When joints in conduit are unavoidable, twin wires should be joined as at *g*, so that the joints are not opposite each other. Joints in flexible cord should be avoided as much as possible.

In splicing stranded wires it is customary to remove some of the center strands to avoid making a very bulky splice. All stranded wires must be soldered where fastened under binding screws, this refers also to flexible cord used in sockets. The best way to solder the ends of cords is to dip them in melted solder, a blow torch will easily overheat small wires and leave them brittle.

Figure 134 shows lead covered wire spliced and taped. In handling lead covered wire great care must be exercised (especially with paper insulated) that it be not bruised and the lead not punctured. The lead covering is of use only as a protection against water, if it admits the least bit of moisture it is worse than useless. The ends of lead covered wires should always be kept sealed until ready for use; in damp places the paper insulation may absorb moisture, which will ground the wire on the lead. When installed the ends should always be sealed against moisture. Lead covered wires should never be used where there is a liability of nails being driven into them.

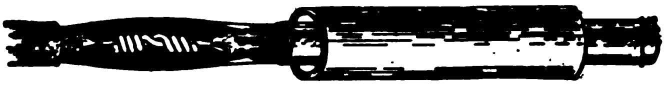


FIGURE 134.

Joints in lead covered wires are made just as in ordinary wires. Extreme care is necessary that no moisture be left on the wire when it is taped or covered up. Before the wire is joined a sleeve (Figure 134) is slipped over one of the wires. After the joint has been made and taped, this sleeve is placed so as to cover it, and the ends split and arranged to fit close against the lead on the wires. That part of the lead which must be soldered to make the joint watertight is scraped until it is perfectly bright and then coated with tallow candle grease. It can then be soldered with an iron, or melted solder can be poured on it and wiped around it, as plumbers do. If a soldering iron is used it must not be too hot. and not allowed to remain in one place too long, as the lead itself melts at nearly the same temperature as the solder. An inexperienced workman may burn more holes into the lead than he closes. If a neat job is desired, that part of the lead which is to be kept free of solder is covered with lampblack and glue, or ordinary paper hanger's paste, or a mixture of flour and water boiled, so as to prevent the solder from taking on it.

d. Must be separated from contact with walls, floors, timbers or partitions through which they may pass by non-combustible, non-absorptive insulating tubes, such as glass or porcelain, except as provided in No. 24 *u.*

Bushings must be long enough to bush the entire length of the hole in one continuous piece or else the hole must first be bushed by a continuous waterproof tube. This tube may be a conductor, such as iron pipe, but in that case an insulating bushing must be pushed into each end of it, extending far enough to keep the wire absolutely out of contact with the pipe.

The exception mentioned is in regard to wires at outlets where they are required to be in approved flexible tubing from the last insulator to at least one inch beyond plaster, or end of the cap on gas piping. This is shown in Figure 135. The reason for the separation of wires from everything but their insulating supports are many. Should a bare live wire come in contact with damp woodwork or masonry, there would very likely be some flow of current to ground and through the ground to the other pole of the dynamo or other wire. This flow of current may gradually char the woodwork, and in time start a fire, or it may gradually eat away the wire, finally causing it to break. When a wire is eaten away, as shown at *c* and *e,* Figure 136, if it is carrying much current, the thin part will become very hot and will set fire to whatever inflammable material may be near it. If the current flow to the ground continues, the positive wire will finally be entirely severed, and an arc, similar to that noticed in an ordinary arc lamp, will be established, and will continue until the wire has been burned away

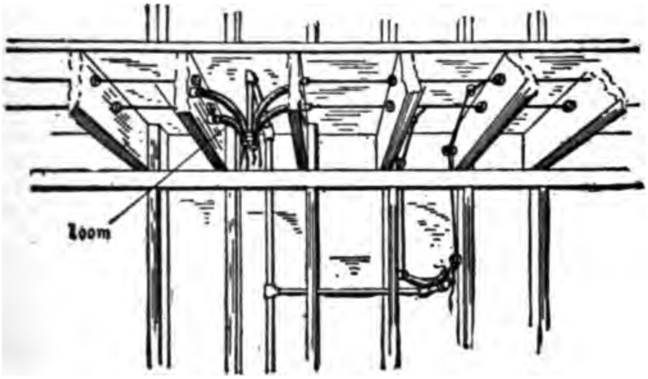


FIGURE 135.

and the space between the two ends becomes too great for the arc to maintain itself. The negative wire, to which the current flows, is not eaten away in this manner, and such current flow is only possible when two wires of a system are in electrical connection with the ground. This action may, however, occur, even if the two grounded wires are miles apart. Wires and gas pipes are often destroyed through intermittent contact, for instance, if a wire makes a good contact to a gas pipe and there is a small leak to the pipe no particular harm will be done as long as the contact remains good. Should, however, the contact be intermittent, there will be a small arc at each break, and this will, little by little, burn holes into the gas pipe and into the wire. This action will take place on either a positive or negative wire. Non-combustible supports for wires are farther useful in that they tend to prevent flames from the rubber insulation (which is very easily ignited from any of the above causes) from spreading to surrounding material.

Figure 136 consists of copies of specimens showing effects of electrolysis, short circuits, and heating of lamp. These illustrations are copied from fire reports of the National Board of Underwriters.

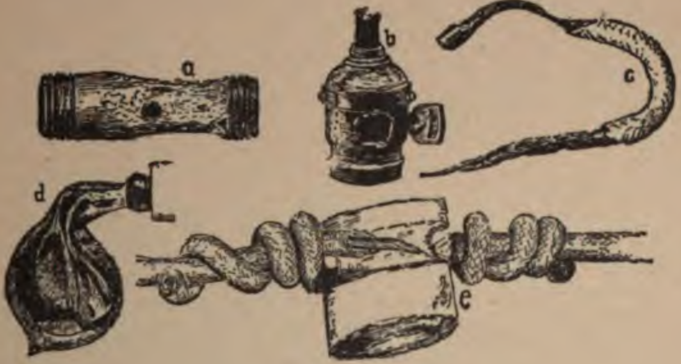


FIGURE 136.

At *a* is shown a piece of gas pipe, which had been subject to electrolytic action until finally a hole had been eaten through the metal, *b* is a socket which had been short circuited, and the excessive damage was due to over-fusing of circuit.

At *c* and *e*, the effects of electrolysis on wire are shown *c* is a piece of underwriter's wire (not approved in moulding), which had been used in damp moulding, the leak to ground through the dampness causing the gradual eating away of the wire, *e* shows a breakdown in the insulation and subsequent electrolytic action on the wire, causing it finally to break. This wire had been used in a round-house, where the sulphur fumes and the condensation of escaping steam on insulators had formed a path to ground. At *d* is an incandescent lamp which had been covered with a towel, the confined heat softening the glass and setting fire to the towel. The danger of fire from overheated lamps is much greater than is generally supposed. Small lamps and lamps subject to a little excess of voltage are especially dangerous, and many instances are on record where they have charred woodwork and set fire to cloth or paper shades.

It may in many cases seem unnecessary to have bushings in one piece long enough to pass through a floor, or wide wall; but especially in passing through floors, it is very easily possible for wires to become crossed between the joists, that is, the wire entering at the right above the floor may be brought out at the left below the floor and the other wire through the opposite holes. In such a case the two wires of opposite polarity will be in contact, and should the insulation give out from any cause whatever, such as abrasion, or the gnawing of rats and mice, there would be nothing to prevent a short circuit and consequent fire. In passing through floors or walls the wires often come in contact with concealed pipes or other grounded material, so that only by making the bushings continuous can the wires be properly protected.

Figure 138 shows short bushings arranged in iron pipe. Figure 139 shows a case where there is an offset in the wall. Cases of this kind very often occur. Sometimes the floor can be taken up and an iron conduit, properly bent, put in place; or the wires placed on insulators. In this latter case the floor must not be put down until the inspector has examined the wires. The wires may be run on top of the floor to such a place where a continuous bushing may be dropped through the floor. The wires on top of the floor must be then protected by a suitable boxing or at least the same dimensions as given for boxing on side walls.

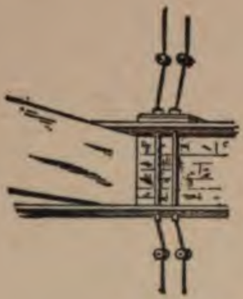


FIGURE 137.

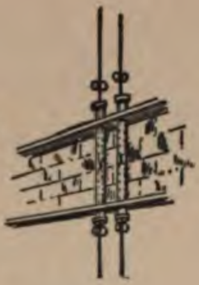


FIGURE 138.

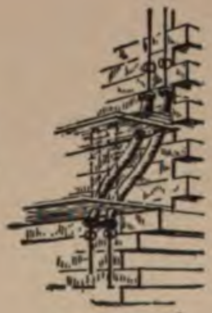


FIGURE 139.

e. Must be kept free from contact with gas, water or other metallic piping, or any other conductors or conducting material which they may cross, by some continuous and firmly fixed non-conductor, creating a separation of at least one inch. Deviations from this rule may sometimes be allowed by special permission.

When one wire crosses another wire the best and usual means of separating them is by means of a porcelain tube on one of them. The tube should be prevented from moving out of place, either by a cleat at each end, or by taping it securely to the wire.

The same method may be adopted where wires pass close to iron pipes, beams, etc., or, where the wires are above the pipes, as is generally the case, ample protection can frequently be secured by supporting the wires well with a porcelain cleat placed as nearly above the pipe as possible.

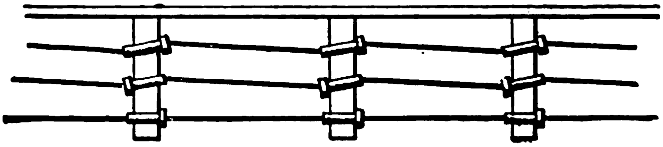


FIGURE 140.

Figure 140 is a sectional view of the manner in which wires are usually run through joists in bushings. For small wires bushings should preferably be installed as shown at top; never as shown in the middle row. For larger wires the holes must be bored as straight as possible, otherwise it will be difficult to pull wires through. The quantity of wire needed is also somewhat increased by slanting the holes. In open places wires are generally installed on insulators as shown in Figure 141.

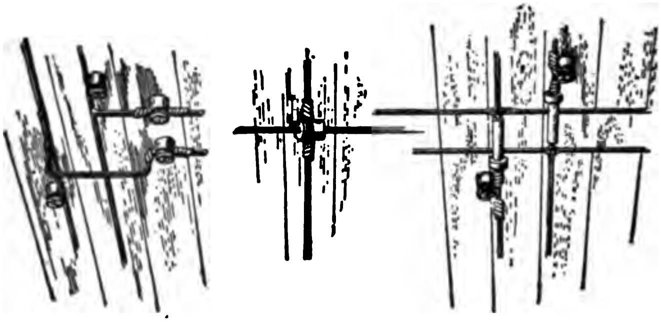


FIGURE 141.

Figure 141 shows different methods employed where one wire crosses another. The method at the left, which is more suited to large stiff wires, does not quite comply with the rule, but is very often used. The other two methods are preferable. Insulating supports should always be provided at the place of crossing to prevent the upper wires from sagging and resting on the lower; also to prevent any strain from coming on tap joints. Approved flexible tubing such as circular loom is also often used in crossing wires and pipes. In dry locations it is quite safe and does not break as easily as tubes, but should never be used where there is any likelihood of dampness.

f. Must be so placed in wet places that an air space will be left between conductors and pipes in crossing, and the former must be run in such a way that they cannot come in contact with the pipe accidentally. Wires should be run over rather than under pipes upon which moisture is likely to gather or which, by leaking, might cause trouble on a circuit.

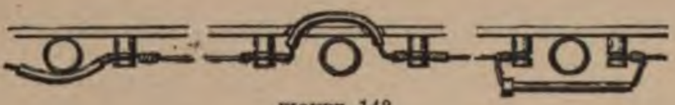


FIGURE 142.

This is a rule that is very often violated, as much work is done using loom, as shown at the left of Figure 142 and is quite safe with gas pipes. With cold water pipes, which are likely to sweat, or with steam pipes, it is very bad practice. Where pipes are close against a ceiling it is better either to fish over them or drop wires some distance below them as illustrated at the right of the figure. No part of the wiring should be in contact with pipes. On side walls where vertical wires run across horizontal pipes the only safeguard would be to box the pipes and run the moisture to one side. The most harm is done by water on the insulators. If these can be kept dry it does not matter much about wires which hang free in the air. Whatever form of insulation is used in crossing pipes, it must be continuous. Short bushings strung on the wire, where a large pipe or number of pipes are being crossed, is not satisfactory, as the bushings are apt to separate or moisture gather in the space between them. The insulation must also be firmly attached to the wires. If knobs are not used as shown in Figure 141 to keep the bushings in place, they must be taped to the wire.

g. The installation of electrical conductors in wooden moulding or where supported on insulators in elevator shafts will not be approved, but conductors may be installed in such shafts if encased in approved metal conduits.

Wires supported on insulators in such places are very likely to be disturbed, especially in freight elevators. Moulding is often so impregnated with oil, and the draft in an elevator shaft is usually so strong that a blaze once started would quickly run to the top.

15. Underground Conductors.

a. Must be protected against moisture and mechanical injury where brought into a building, and all combustible material must be kept from the immediate vicinity.

b. Must not be so arranged as to shunt the current through a building around any catch-box.

By reference to Figure 143 the meaning of this rule will be made clear. With wires run as shown it would be easy for any one having disconnected one service switch to believe all wires in the building dead, while they were in reality still being kept alive by the other switch.

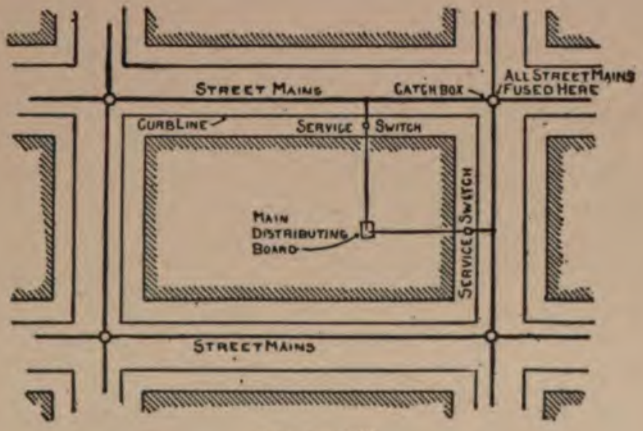


FIGURE 143.

c. Where underground service enters building through tubes, the tubes shall be tightly closed at outlets with asphaltum or other non-conductor, to prevent gases from entering the building through such channels.

d. No underground service from a subway to a building shall supply more than one building, except by written permission from the Inspection Department having jurisdiction.

17. Switches, Cut-Outs, Circuit-Breakers, Etc.

(For construction rules see Nos. 51, 52 and 53.)

a. Must, unless otherwise provided (for exceptions, see No. 8 *c* and No. 22 *c*), be so arranged that the cut-outs will protect, and the opening of a switch or circuit-breaker will disconnect all of the wires, that is, in a two-wire system the two wires, and in a three-wire system the three wires, must be protected by the cut-out and disconnected by the operation of the switch or circuit-breaker.

The exceptions are in regard to motors of ¼ H. P. or less on circuits of not over 300 volts and incandescent circuits of not over 660 watts where single pole switches are allowed. This rule forbids the practice, as sometimes employed on switchboards, of breaking the two outside wires of a 3-wire system and leaving the neutral, which is not carried through the switch, always connected.

In connecting double-pole snap switches the wireman should be very careful. Most of these switches cross polarities as shown in Figure 144, and if connected wrong will form short circuits. Many of them have been connected that way, even by wiremen of some experience.

b. Must not be placed in the immediate vicinity of easily ignitable stuff or where exposed to inflammable gases or dust or to flyings of combustible material.

In starch and candy factories, grain elevators, flouring mills, and buildings used for woodworking or other purposes which would cause the fittings to be exposed to dust and flyings of inflammable material, the cut-outs and switches should be placed in approved cabinets outside of the dust-rooms. If, however, it is necessary to locate them in the dust-rooms, the cabinets must be dust-proof and must be provided with self-closing doors.

Whenever an electric current is broken, whether by fuse or switch, an arc varying with the current strength, is formed. Should a switch be only partly opened, this arc will continue and consume the metal of the switch until the gap in which it burns becomes too long, when the current will be broken. Meanwhile there is much heat generated which may readily communicate to inflammable material nearby.

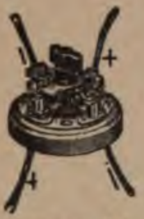


FIGURE 144.

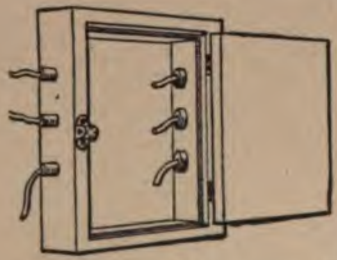


FIGURE 145.

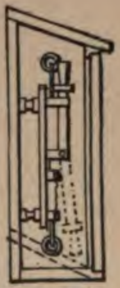


FIGURE 146.

There seems to be no reason except economy of wire why cut-outs should ever be placed inside of dust-rooms. Switches of course must often be placed in such rooms as in many cases the entire building outside of the engine room is dusty. In such cases the switches as well as the cut-outs may, however, be often placed on the outside walls convenient to some window.

An approved cabinet is shown in Figure 145. If used in connection with knife switches it should be large enough to admit being closed when the switch is open. In cases where cut-outs and switches must be located in dusty rooms, it would be well to construct double cabinets, one part for the cut-outs and another for the switches. The fuses, which are the most dangerous, can then be tightly enclosed, as it will seldom be necessary to get at them. In practice it has been found almost impossible to keep the doors of cabinets which are much used closed. It seems next to impossible to construct a cabinet which is dust-proof, with a door that can be readily opened, and a self-closing door can hardly be made to remain dust-proof. Doors are made self-closing either through gravity or by suitable springs.

As switch and cut-out boxes are very likely to be used for the storage of cotton waste, paper, etc., which would readily ignite from a melted fuse, it would be well to construct them with a slanting bottom as indicated by the dotted line in Figure 146, so that nothing will lie in them.

c. Must, when exposed to dampness, either be enclosed in a waterproof box or mounted on porcelain knobs.

Figure 146 is a sectional side view of a cut-out box for use out of doors. In it the switch is mounted on porcelain knobs. In all damp places much trouble is experienced from leakage through the moisture on the surface of the slate or marble and through the wax used to cover the bare parts on back of switch.

d. Time switches must be enclosed in an iron box or cabinet lined with fire resisting material.

If an iron box is used, the minimum thickness of the iron must be 0.128 of an inch No. 8 B. & S. Gauge).

If the cabinet is used, it must be lined with marble or slate at least ⅜ of an inch thick, or with iron not less than 0.128 of an inch thick. Box or cabinet must be so constructed that when switch operates blade shall clear the door by at least one inch.

CONSTANT-CURRENT SYSTEMS.

PRINCIPALLY SERIES ARC LIGHTING.

18. Wires.

(See also Nos. 14, 15 and 16.)

a. Must have an approved rubber insulating covering (see No. 41).

b. Must be arranged to enter and leave the building through an approved double-contact service switch (see No. 51 *b*), mounted in a non-combustible case, kept free from moisture, and easy of access to police or firemen.

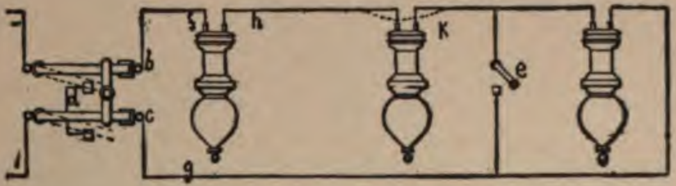


FIGURE 147.

In order that all of the wiring in the building may be entirely disconnected a switch, the principle of which is illustrated at *d*, Figure 147, is provided where wires enter and leave the building. A modern commercial form of this switch is shown in Figure 148. This switch never breaks the circuit. As shown in Figure 147, the current passes from the positive pole, through the upper blade of the switch to *b* and thence through the arc lamps back to *c* and to the negative pole. When it is desired to extinguish the lamps the two blades of the switch are moved downward, as indicated by the dotted lines. The contacts *d* are arranged so that both switch blades connect with them before disconnecting entirely from the points *b* and *c*. As soon as both blades are in contact with *d* all current flows through it because the resistance of it is so very much less than that of the lamps. With the switch in the position indicated by dotted lines, the current still flows in the outside wires, but all wires within the building are dead. At *e*, Figure 147, is shown a single-pole switch which operates on the same principle as the other. If this switch is closed all current will pass through it, if open the current will pass through the last lamp. A switch of this kind is always arranged within the lamp itself. This latter way of switching lamps should never be used, as a lamp switched in this way is never safe to handle. There is just as much danger from shocks when the lamp is switched off as when on.

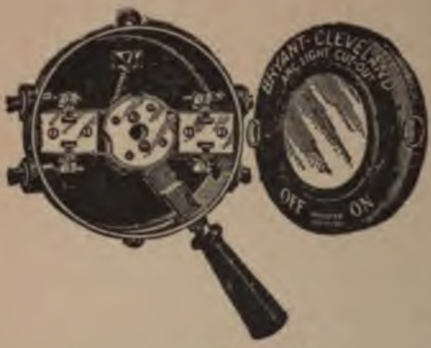


FIGURE 148.

With switches as described above there is no spark whatever when lamps are switched off, but there is usually quite a spark when the lamps are switched in. Should there be a broken wire, or a lamp out of order in the circuit to be switched in, there will be quite an arc maintained for some time. In such a case the switch should be quickly closed and the trouble located.

In handling live wires of this system great care is necessary. The wireman should insulate himself from the ground by a dry board, or, if all about him is damp, by a board resting on insulators. Rubber gloves and rubber boots, if kept dry, are useful.

Death or bad burns may result if the wireman, standing on wet ground or any conductor in connection with it, touches part of a circuit which is also partly in connection with the ground. If, in Figure 147, the wire at *f* is grounded, a man in connection with the ground and touching a bare wire at *h* will receive a shock due to about 50 volts, but if he touches the wire at *g*, he will receive a shock of about 150 volts. The shock received from a line containing 100 lamps may be anything from 50 to 5,000 volts, and may result in only a slight burn or in instant death.

Another danger in connection with live circuits is the liability of cutting oneself into circuit. If one is perfectly insulated from the ground there is no harm whatever in touching one live wire (with very high voltages such insulation is, however, hard to obtain) with either one or both hands while the wires are in order. Should, however, the wire between the two hands break, the current would immediately pass through the body, very likely causing instant death. Even if the circuit is not entirely broken, if only a resistance is cut in, the shock will be very severe. As, for instance, if one should touch the terminal of an arc lamp, not burning, with each hand nothing whatever would be felt, but, if the lamp were now suddenly switched on, there would be a very severe shock at first, which would become less so when the lamps were fairly started. To avoid the possibility of such occurrences when working on live lamps or circuits a short wire known as a jumper is often connected, as at *k*, Figure 147. This will carry all current, and there is now no danger except from a connection to ground.

c. Must always be in plain sight, and never encased, except when required by the Inspection Department having jurisdiction.

What is known as concealed knob and tube work is not allowed in wiring for H. T. arcs, neither can the wires be run in moulding or conduit.

It has been customary to use no smaller than No. 6 wire for these high tension series circuits. The current required is seldom more than 10 amperes, and No. 14 wire has sufficient carrying capacity, but its mechanical strength is not very great. The danger from a broken wire in high tension systems is much greater than in low tension systems, because of the long arc which occurs at the break. The loss in volts per 100 feet with No. 6 will be about .4, when with No. 14 it will be 2.6. This, however, will not affect the lights, because the pressure at the machine must be correspondingly increased.

d. Must be supported on glass or porcelain insulators, which separate the wire at least one inch from the surface wired over, and must be kept rigidly at least eight inches from each other, except within the structure of lamps, on hanger-boards or in cut-out boxes, or like places, where a less distance is necessary.

An extra precaution often taken in this kind of work on plastered walls is to place a wooden block or rosette about three inches in diameter and one-half inch thick under each insulator; this secures greater separation from ceilings and side walls and adds greatly to the stability of the insulators. On plastered walls a small insulator, if subjected to side strain, will cut into the plaster on one side and allow the wires to sag, the wooden block will prevent this.

c. Must, on side wall, be protected from mechanical injury by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes), and extending not less than seven feet from the floor. When crossing floor timbers in cellars, or in rooms where they might be exposed to injury, wires must be attached by their insulating supports to the under side of a wooden strip not less than one-half an inch in thickness. Instead of the running-boards, guard strips on each side of and close to the wires will be accepted. These strips to be not less than seven-eighths of an inch in thickness and at least as high as the insulators.

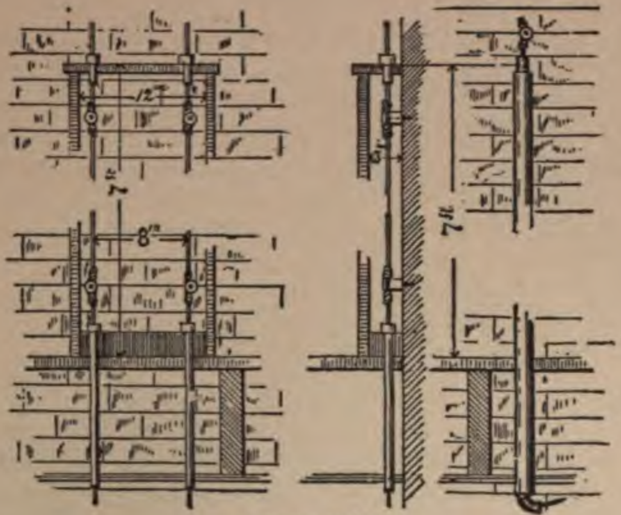


FIGURE 149.

Except on joisted ceilings, a strip one-half of an inch thick is not considered sufficiently stiff and strong. For spans of say eight or ten feet, where there is but little vibration, one-inch stock is generally sufficiently stiff; but where the span is longer than this or there is considerable vibration, still heavier stock should be used.

For general suggestions as to protecting wires on side walls, see notes under No. 24 *e*.

Figure 149 is an illustration of protection on side walls, giving the dimensions required. The wooden block shown, which raises bushings above floor, is an extra protection to prevent water from running into them. The iron pipe is shown extending in one piece clear through the floor. With voltages used in this system a separate pipe should be provided for each wire, unless alternating currents are used.

19. Series Arc Lamps.

(For construction rules, see No. 57).

a. Must be carefully isolated from inflammable material.

b. Must be provided at all times with a glass globe surrounding the arc, and securely fastened upon a closed base. Broken or cracked globes must not be used.

c. Must be provided with a wire netting (having a mesh not exceeding one and one-fourth inches) around the globe, and an approved spark arrester (see No. 58), when readily inflammable material is in the vicinity of the lamps, to prevent escape of sparks of carbon or melted copper. It is recommended that plain carbons, not copper-plated, be used for lamps in such places.

Outside arc lamps must be suspended at least eight feet above sidewalks. Inside arc lamps must be placed out of reach or suitably protected.

Arc lamps, when used in places where they are exposed to flyings of easily inflammable material, should have the carbons enclosed completely in a tight globe in such manner as to avoid the necessity for spark arresters.

"Enclosed arc" lamps, having tight inner globes, may be used, and the requirements of Sections b and c above would of course, not apply to them, except that a wire netting around the inner globe may in some cases be required if the outer globe is omitted.

d. When hanger-boards (see No. 56) are not used, lamps must be hung from insulating supports other than their conductors.

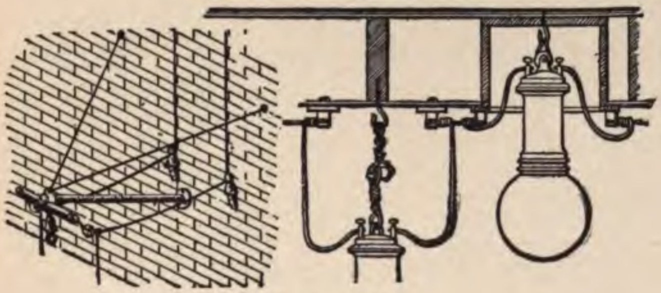


FIGURE 150.

At the left, Figure 150 is shown, the usual method of suspending outdoor arc lamps on buildings. The supporting wire may be fastened to brick or stone walls by drilling a hole about four inches deep and plugging this securely with wood, when an eye or lag bolt or large spike may be driven or screwed into it. Expansion bolts, of which there are many kinds to be had, may also be used. It is best to arrange the supporting wires at quite a high angle, otherwise the direct outward pull may be too great. Some of the older arc lamps are not provided with insulators, and may be suspended, as shown in the center of the figure. On very low ceilings, lamps are often arranged as shown at the right, the plastering being cut away and lamp suspended from floor above joists. The space above plaster must be enclosed on all sides and all woodwork protected with asbestos board at least one-eighth inch thick.

If this method is used with constant potential arc lamps carrying resistance in the hood, it would be well to remove or short-circuit this resistance and locate another in a more suitable place.

20. Incandescent Lamps in Series Circuits.

a. Must have the conductors installed as required in No. 18, and each lamp must be provided with an automatic cut-out.

b. Must have each lamp suspended from a hanger-board by means of rigid tube.

c. No electro-magnetic device for switches and no multiple-series or series-multiple system of lighting will be approved.

d. Must not under any circumstances be attached to gas fixtures.

CONSTANT-POTENTIAL SYSTEMS.

GENERAL RULES—ALL VOLTAGES.

21. Automatic Cut-Outs (Fuses and Circuit-Breakers).

(See No. 17, and for construction, Nos. 52 and 53.)

Excepting on main switchboards, or where otherwise subject to expert supervision, circuit-breakers will not be accepted unless fuses are also provided.

The cut-out is the principal protective device used in electric light and power work. In its simplest form it consists of a piece of wire made of a certain alloy designed to melt at a comparatively low temperature and so connected that all current used in a certain circuit must pass through it. We have already seen that currents of electricity generate heat in the conductors through which they pass, and that this heat is proportional to the square of the current flowing; that is, if we double the current we shall increase the production of heat fourfold. A dangerous rise in current strength may be due to a short circuit or to an overload, too many lamps or motors being connected to a circuit. To prevent damage to wires and other apparatus from excessive currents, fuses or cut-outs must be installed. When the current rises above its allowed strength the fuse melts and opens the circuit; that is, stops all current flow. This melting of the fuse is always accompanied by a flash of fire, called an arc, and may easily set fire to inflammable material located near the fuses. In the case of large fuses pieces of molten lead are often spattered about.

Another device used for the same purpose as the fuse or cut-out is known as the circuit breaker. A circuit-breaker in its simplest form comprises a knife switch which when closed is forced in against a spring and held in place by means of a small catch. A solenoid, inside of which is placed a moveable iron core, is connected in series with one side of the switch. When the current passing through this solenoid exceeds a certain amount, the iron core is drawn up into it, and, striking against the catch, releases the switch which will then fly open, thus cutting off the current. The core of this solenoid is so designed that when it starts to move its speed is greatly accelerated so that it strikes the catch a sharp blow. By means of a small adjusting screw the circuit breaker can be set to operate at various current strengths within its limits. For this reason and for the further reason that it is so easily made inoperative by tying or blocking its solenoid it is not approved for general use unless fuses are also installed. It may be used under the care of a competent electrician who understands the dangers of its abuse.

a. Must be placed on all service wires, either overhead or underground, as near as possible to the point where they enter the building and inside the walls, and arranged to cut off the entire current from the building.

Where the switch required by No. 22 is inside the building, the cut-out required by this section must be placed so as to protect it.

In risks having private plants, the yard wires running from building to building are not generally considered as service wires, so that cut-outs would not be required where the wires enter buildings, provided that the next fuse back is small enough to properly protect the wires inside the building in question.

The fuse block here required serves a double purpose; it affords protection to the whole installation while in use, and is an effective means of disconnecting a building when current is no longer used. This can also be accomplished by means of the service switch, but a switch is so easily closed by anyone that it must never be relied upon entirely for this purpose.

Figure 151 shows arrangement of fuses and switch as commonly installed where wires enter buildings. The wires enter at the top, connect to the fuse terminals, current passing through the fuses to the switch.

b. Must be placed at every point where a change is made in the size of wire [unless the cut-out in the larger wire will protect the smaller. (see No. 61).]

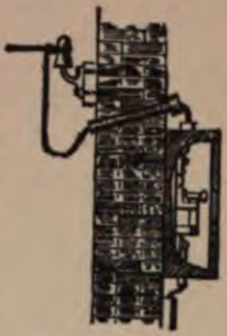


FIGURE 151.

Figure 152, A to D, shows systems of distribution and arrangement of mains in general use. A shows the simplest and cheapest method of running mains, and is known as the tree system. Beginning at the service the wires must be large enough to carry the whole current to the first floor or wherever the first cut-out center is located. At this point the size of wire may be reduced because it will be required to carry only the current used further on. Main cut-outs should be arranged as shown in the figure at 1 and 2. That is, the cut-outs protecting the mains must be installed in the mains at each floor after the current for that floor has been taken off. Cases are often found where the cut-out is placed in the main line ahead of the branch blocks. This is obviously wrong, as the fuse will have to be too heavy to protect the smaller mains.

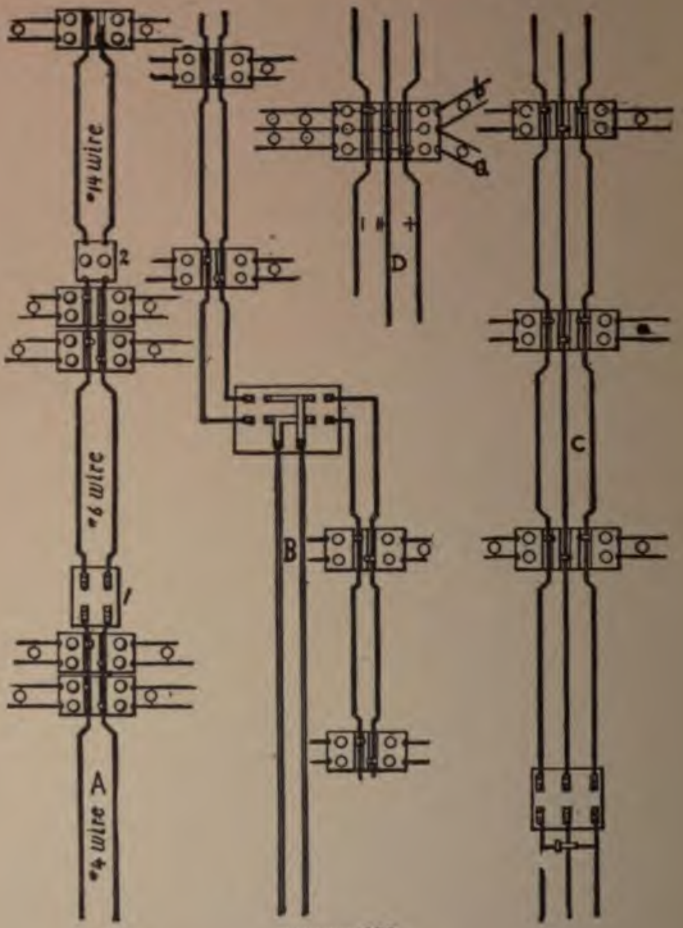


FIGURE 152.

B shows a somewhat different arrangement which requires more wire and is more expensive in the beginning, but far more satisfactory and economical in operation. With the wires arranged as shown in the diagram the pressure at all the lamps will be nearly uniform. Even if the mains are designed for a considerable loss to the center of distribution the dynamo may be made to compensate for this loss and keep the lamps burning properly. With the tree system, A, this is impossible: the lamps at the first cut-out center will either be too bright or those at the last center too dim.

C shows a convertible three-wire system. Three-wire circuits may also be run as shown in A and B, using three instead of two wires.

In order to convert a three-wire system into a two-wire system the two outside wires are joined together. The middle wire then forms one side of the system and the outside wires the other. The middle wire must carry as much current as both outside wires combined and should have a carrying capacity equal to them.

In three-wire systems the middle or neutral wire is merely a balancing wire and normally carries very little or no current, but it is very important that it remain intact. If for instance in D the branch circuit *a* has twelve lights burning while there are also 12 lights burning on *b*, the current will pass from the positive wire through the lower fuse to *a*, through the twelve lights in *a* back to the middle fuse, thence through the 12 lights in *b* to the upper fuse and negative wire, the two sets of lamps burning in series. If now the lamps in *b* are switched off, the current from *a* can no longer pass through them and instead returns through the middle fuse to the neutral wire. If only six lights in *b* are burning, while 12 are burning in *a*, the current of 6 lights will return over the negative wire and the other six in *a* will return over the neutral wire. Should the neutral wire be broken or its fuse blown there would be no return path on it for the extra current, and consequently the current passing through the twelve lights in *a* would be forced through the six lights in *b*, causing them to burn with excessive brilliancy and to break in a very short time. Should a short circuit occur, say on circuit *b*, with the neutral wire intact, it would merely blow a fuse, but if the main neutral fuse were out it would bring 220 volts on circuit *a* and speedily cause damage to the lamps. Thus it will be seen that it is of great importance to fuse the neutral wire so that it will not easily blow out. The cut-out shown in D is not approved because it does not provide independent double fused branch circuits. The style of wiring shown in connection with it was formerly much in vogue but is not now much used.

C shows a system of wiring quite often used. A set of heavy mains are run from the service or dynamo to the top floor and taps taken off at each floor. These mains do not change size at each floor, but are continuous for their entire length. While this method has some of the objections of the tree system in regards to voltage, still the faults of the tree system are greatly reduced to the much smaller losses in the mains between the upper floors or those farthest from the dynamo.

Figure 153 shows the method of fusing main switch and branch circuits. The switch itself will require a fuse to protect it although it need not be right at the switch.

It often becomes necessary to reinforce a set of mains, especially for motors which have become overloaded, by running another wire in parallel with the old as indicated in Figures 154 and 155. Two separate and distinct ways of arranging them are shown and it depends upon the conditions as to which is preferable. If the wires are small or run in places where they are liable to be broken, the plan shown in Figure 154 is the better. Here each wire is properly fused and if one breaks the other carries the whole load until its fuse melts. If the wires, as often happens, are much overfused, the breaking of one wire would force the other to carry the whole current and become overheated. If the arrangement were as in Figure 155, the unbroken wire would carry the current indefinitely and soon become overheated. On the other hand, if both wires are large and the run is short the fuses arranged as in Figure 154 may, through poor contacts, prevent one or the other of the wires from obtaining its full share of the current. The fuse making poor contact would force a much greater share of current through the other wire. In most cases the better plan would be to arrange the wires as in Figure 155. If the current supplied is for lights the branch cut-outs can be separated and each set of mains allowed to supply a certain part of them, when each set should be made independent. For sizes of wires to be used for reinforcing, see Tables.

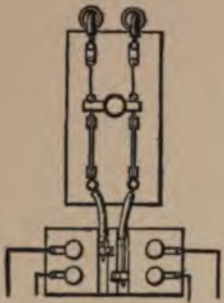


FIGURE 153.

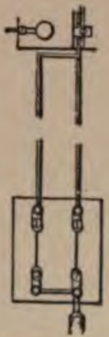


FIGURE 154.

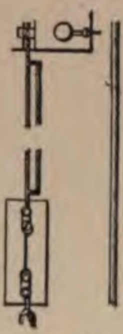


FIGURE 155.

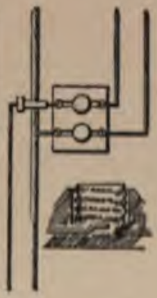


FIGURE 156.

With the three-wire system where a larger motor load and a few lights are run the lights are often fused as shown in Figure 156, a small wire being run for the neutral, this smaller wire, of course, being properly fused at the main cut-out. Plug cut-outs of the type shown in this figure often have the metal parts projecting above the porcelain; they should be connected so that the metal parts which project are dead when the plugs are removed. This will prevent many short circuits on disconnected cut-outs.

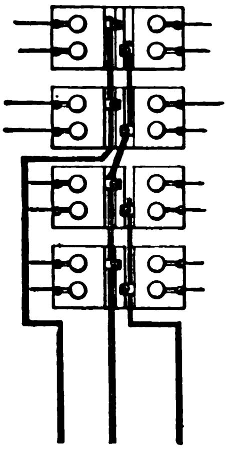


FIGURE 157.

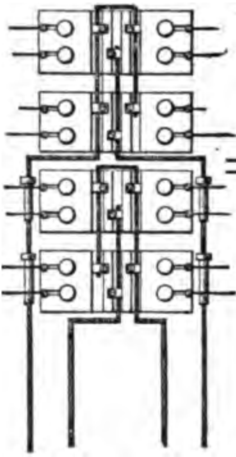


FIGURE 158.

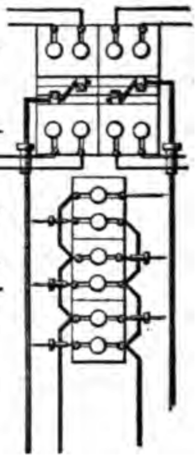


FIGURE 159.

Figure 157 shows the method of converting a two-wire system into a three-wire system with one extra wire to run. This extra wire will very likely not need to be as large as the other wires are, because the three-wire system requires only one-half as much current and it should, therefore, be used as the neutral. This arrangement will secure the full benefit of all the copper in the old wires (which are probably much larger than necessary) and will operate at a very small loss.

Figure 158 shows a straight three-wire system changed to a two-wire system, one extra wire run for it. If the three wires are of the proper capacity the addition of the fourth wire as in the figure will make it correct for two-wire systems, the mains feeding the upper and lower groups being, of course, properly fused where they start.

In Figure 159 the cut-outs are so connected that all branch wires leaving the cut-out box at either side are of the same polarity. This is often useful where many wires are to be run close together.

c. Must be in plain sight, or enclosed in an approved cabinet (see No. 54), and readily accessible. They must not be placed in the canopies or shells of fixtures.

The ordinary porcelain link fuse cut-out will not be approved. Link fuses may be used only when mounted on slate or marble bases conforming to No. 52 and must be enclosed in dust-tight, fireproofed cabinets, except on switchboards located well away from combustible material, as in the ordinary engine and dynamo room and where these conditions will be maintained.

While it is required that cut-out cabinets be accessible there is also danger in making them too accessible, for such cabinets are very often used for storage of paper or cotton waste. It would seem that about eight feet above the floor is the most desirable height to place them or the cabinet may be arranged with a slanting bottom which will make it impossible to store anything in it. It is also well to arrange the cut-out cabinet away from inflammable material, for long experience has shown that doors are nearly always left open. Especially is this the case when switches are in the same cabinets with the cut-outs.

d. Must be so placed that no set of incandescent lamps requiring more than 660 watts, whether grouped on one fixture or on several fixtures or pendants, will be dependent upon one cut-out. Special permission may be given in writing by the Inspection Department having jurisdiction for departure from this rule in the case of large chandeliers, stage borders and illuminated signs.

The above rule shall also apply to motors when more than one is dependent on a single cut-out.

The idea is to have a small fuse to protect the lamp socket and the small wire used for fixtures, pendants, etc. It also lessens the chances of extinguishing a large number of lights if a short circuit occurs.

On open work in large mills approved link fused rosettes may be used at a voltage of not over 125 and approved enclosed fused rosettes at a voltage of not over 250, the fuse in the rosettes not to exceed 3 amperes, and a fuse of over 25 amperes must not be used in the branch circuit.

All branches of taps from a three-wire Edison system must be run as two-wire circuits.

e. The rated capacity of fuses must not exceed the allowable carrying capacity of the wire as giver in No. 16. Circuit-breakers must not be set more than 30 per cent above the allowable carrying capacity of the wire, unless a fusible cut-out is also installed in the circuit.

A 16 cp. incandescent lamp is usually estimated at 55 watts and consequently the number of lamps allowed on one circuit is usually twelve, whether 110 or 220 volts are used. If voltages lower than 110 are used the current required by twelve 55 watts lamps will be too great, and fewer lamps should be used per circuit. Although a number of small fan motors may be run on one circuit each motor should be provided with a switch; as a rule such a switch is on the motor.

22. Switches.

(See No. 17, and for construction, No. 51.)

a. Must be placed on all service wires, either overhead or underground, in a readily accessible place, as near as possible to the point where the wires enter the building and arranged to cut off the entire current.

Service cut-out and switch must be arranged to cut off current from all devices including meters.

In risks having private plants the yard wires running from building to building are not generally considered as service wires, so that switches would not be required in each building if there are other switches conveniently located on the mains or if the generators are near at hand.

In overhead construction the best plan is to locate the switch at either front or rear of building so that wires may lead to it direct from pole. Avoid running wires on sides of building where it is likely that other buildings may be erected. In underground construction, where the space under sidewalk and basement is not occupied, it is advisable to place a cut-out where wires enter the building from street and to locate the service switch in a more accessible place.

Although the rules do not call for switch to be installed in each separate building in the case of large plants, still it is often advisable to install them, for in case of trouble it is necessary that the current can be immediately shut off. A switch is also useful in cases of trouble on the wiring, to allow of repairing.

b. Must always be placed in dry, accessible places, and be grouped as far as possible. Knife switches must be so placed that gravity will tend to open rather than close them.

When possible, switches should be so wired that blades will be dead when switch is open.

If knife switches are used in rooms where combustible flyings would be likely to accumulate around them, they should be enclosed in dust-tight cabinets. (See note under No. 17 b.) Even in rooms where there are no combustible materials it is better to put all knife switches in cabinets, in order to lessen the danger of accidental short circuits being made across their exposed metal parts by careless workmen.

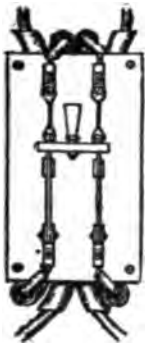


FIGURE 160.

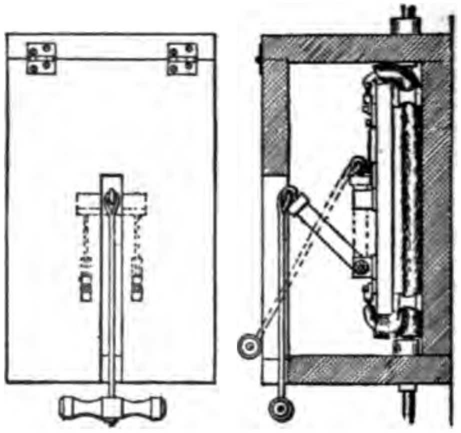


FIGURE 161.

Up to 250 volts and thirty amperes, approved indicating snap switches are advised in preference to knife switches on lighting circuits about the workrooms.

To comply with this rule wil ordinarily bring the fuses of knife switches directly under the handle of switch. If there happens to be a short circuit on the wires when switch is closed the fuses will blow instantly and very likely burn the operator's hand. In connection with such switches cartridge fuses should be used or the switches, especially the larger ones, closed by pushing them in with a stick. The danger from opening a switch is much less.

Figure 160 shows a switch arranged to comply with all three points of this rule, the feed wires coming from below. This requires that incoming and outgoing wires pass each other. In this case, the wires pass each other behind the switch base, they being encased in flexible tubing. A side view is also given in Figure 161. Instead of passing behind the switch the wires may, of course, run around one side to the top, the other wires around the other side to the bottom.

Figure 161 illustrates a cabinet so arranged that the switch within can be opened or closed without opening the cabinet. The cover is hinged at the top, and slotted in the center, which leaves room for the lever by which the switch is worked to adjust itself so it will always be out of the way. A switch which is often used may as well be left without a cover as with one, for the door must be opened or closed every time the switch is used, and the cabinet will always be found open. Figure 161 will answer where only protection against accidental contacts is required.

c. Must not be single pole when the circuits which they control supply devices which require over 660 watts of energy, or when the difference of potential is over 300 volts.

This rule allows the use of single pole switches on circuits of 660 watts, 6 amperes at 110 volts, or 3 amperes at 220 volts, which corresponds roughly to twelve 16 cp. lamps. In systems that are not grounded a single pole switch will answer fairly well if large enough. It will readily open the circuit and it offers no opportunities for short circuits, as do double pole switches. Where, however, three wire systems with grounded neutrals are used double-pole switches are preferable, for by reference to Figure 162 one can readily see that if the neutral or middle wire is grounded (which is equivalent to being in connection with gas piping) and another ground should come on to the wiring say at *a*, the single-pole switch, S, would not control the lights at all. The current would flow from the positive wire to the top fuse, through the twelve lights to ground *a*, through the ground to the neutral or middle wire and back to the dynamo, regardless of whether the switch is on or off. Also a man working at the lights could easily make a short-circuit by bringing the wires into contact with the gas piping even if the switch were turned off. When

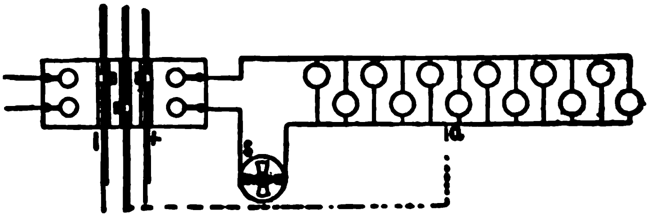


FIGURE 162.

single-pole switches are used in connection with such circuits they should never be placed in the neutral wire as in the diagram. If the switch S were placed in the top wire these troubles would be avoided. Often times, however, switches are connected before the circuits are run into cut-outs and an attempt to place single-pole switches on a certain wire requires considerable care, which many wiremen will not take. In the case of only two wires from a central, three-wire station being run into a building, the neutral wire is not known until meters are set and instructions would, therefore, have to be left for meter men which would often be disregarded, so that in all cases on three-wire grounded systems double-pole switches are preferable.

d. Where flush switches are used, whether with conduit systems or not, the switches must be enclosed in boxes constructed of iron or steel. No push buttons for bells, gas-lighting circuits, or the like shall be placed in the same wall plate with switches controlling electric light or power wiring.

This requires an approved box in addition to the porcelain enclosure of the switch.

e. Where possible, at all switch or fixture outlets, a ⅞-inch block must be fastened between studs or floor timbers flush with the back of lathing to hold tubes, and to support switches or fixtures. When this cannot be done, wooden base blocks, not less than ¾-inch in thickness, securely screwed to lathing, must be provided for switches, and also for fixtures which are not attached to gas pipes or conduit tubing.

Figure 163 shows concealed wiring back of lathing leading to a double-pole flush switch. The board fastened between studdings must be cut out to admit the box of switch and the size of this box should be known when wires are put in. The board should not rest hard against the lathing, but leave a little space for plaster to work in behind the lath. Loom is put on all wires at outlets and must extend back to the nearest knob.

Figure 164 shows two methods of fastening snap switches by means of wooden blocks first fastened to the plaster. One block is cut out so as to bring all wires under the switch and entirely conceal them. The opening in block to admit wires and bushings should be oblong, so as to leave room on two sides for the screws with which the switch is to be fastened. On the other

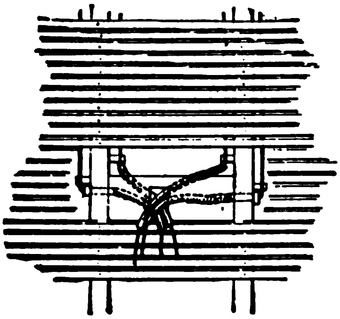


FIGURE 163.

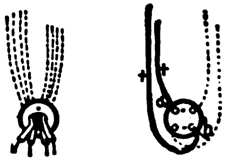


FIGURE 164.

block the wires and bushings are brought through close to the outer edge of switch base. By careful workmanship a neat job can be done in this way. As most snap switches cross conductors, that is, connect points *a* and b, if from the nature of the case it becomes necessary to run any of the wires close together these two wires may be run that way, for they can never be of opposite polarity.

23. Electric Heaters.

a. Must be placed in a safe situation, isolated from inflammable materials, and be treated as sources of heat.

b. Must each have a cut-out and an indicating switch (see No. 17 *a*).

c. The attachments of feed wires to the heaters must be in plain sight, easily accessible, and protected from interference, accidental or otherwise.

d. The flexible conductors for portable apparatus, such as irons, etc., must have an approved insulating covering (see No. 45 *g*).

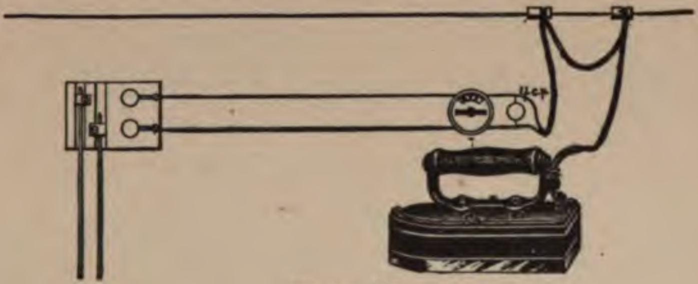


FIGURE 165.

e. Must each be provided with name plate, giving the maker's name and the normal capacity in volts and amperes.

Stationary heaters should be treated like stoves which might become overheated at any time.

Portable heaters, such as flatirons, have this danger, that if left standing with the current on they in time accumulate heat enough to char combustible material and to finally set it on fire.

It is often desirable to connect in multiple with the heaters, an incandescent lamp of low candle power, as it shows at a glance whether or not the switch is open, and tends to prevent its being left closed through oversight.

In Figure 165 is given a diagram of a heater circuit with a 4 cp. lamp in circuit. Where there are many irons in use, as in some tailoring establishments, it is advisable to run them all from one set of mains with a main switch convenient to exit door and have this switch opened whenever the irons are not in use. The individual switch at each iron should be located as near as possible to each iron. Cords feeding irons or cloth cutting machines are often installed as shown, insulators are strung on a tight wire and the cord tied to them. This allows considerable latitude in moving the iron.

LOW-POTENTIAL SYSTEMS.

550 VOLTS OR LESS.

Any circuit attached to any machine, or combination of machines, which develops a difference of potential between any two wires, of over ten volts and less than 550 volts, shall be considered as a low-potential circuit, and as coming under this class, unless an approved transforming device is used, which cuts the difference of potential down to ten volts or less. The primary circuit not to exceed a potential of 3,500 volts.

Before voltage is raised above 300 volts on any previously existing system of wiring, the whole must be strictly brought up to all of the requirements of the rules at date.

24. Wires.

GENERAL RULES.

(See also Nos. 14, 15 and 16.)

a. Must be so arranged that under no circumstances will there be a difference of potential of over 300 volts between any bare metal parts in any distributing switch or cut-out cabinet, or equivalent center of distribution.

This rule, as far as it applies to pressure higher than 300 volts, contemplates a 3-wire system on which, instead of the customary 110 volts on each side of the neutral, 220 volts are used, making a pressure of 440 volts between the two outside wires.

The ordinary 110-220 volt, 3-wire system will require to be changed at cut-out centers as shown in Figure 166, where it will be seen a difference of potential greater than 220 volts cannot be found within any cut-out box, or at any switch or cut-out.

Special attention should be given to the balancing of the load with this arrangement of wiring and both sides of the system should be brought into every room or hall requiring more than one circuit. False ideas of economy should not induce one to arrange large groups of lamps on one side of the system in order to save a few cut-out boxes.

b. Must not be laid in plaster, cement, or similar finish, and must never be fastened with staples.

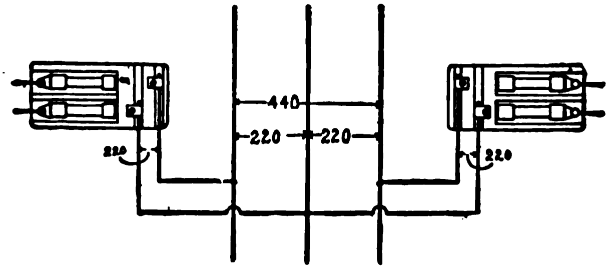


FIGURE 166.

c. Must not be fished for any great distance, and only in places where the inspector can satisfy himself that the rules have been complied with.

Figure 167 illustrates a very common combination of fish and moulding work. Moulding is used to bring the wires from the floor to the ceiling and along the ceiling to a point opposite the outlet and parallel with the joists. From this point to the fixture the wires can then be readily fished.

The connection between the fish and moulding work should be made as shown at the right, where the moulding is cut out so as to admit the loom. It is better, even, to have the loom show to some extent than to have the wire come in contact with the plaster, as will very likely be the case if the loom is not fully brought through.

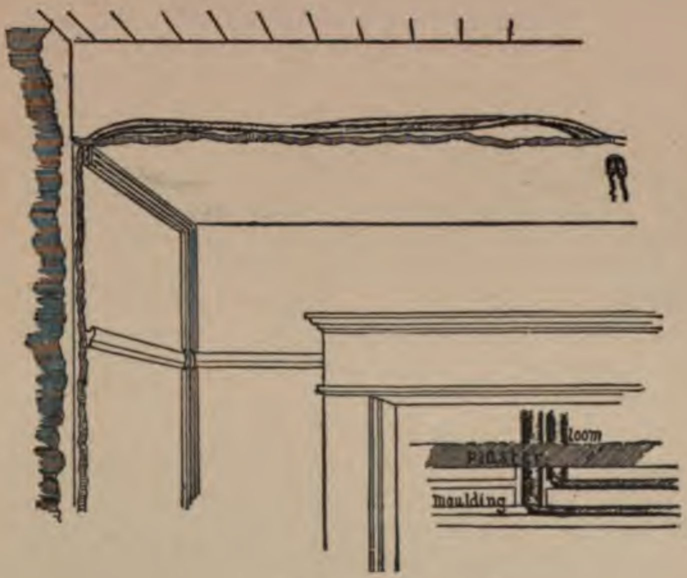


FIGURE 167.

d. Twin wires must never be used, except in conduits, or where flexible conductors are necessary.

Flexible conductors are in general considered necessary only with pendant sockets, certain styles of adjustable brackets, portable lamps, motors and stage plugs, or heating apparatus.

e. Must be protected on side walls from mechanical injury. When crossing floor timbers in cellars, or in rooms where they might be exposed to injury, wires must be attached by their insulating supports to the under side of a wooden strip, not less than one-half inch in thickness, and not less than three inches in width. Instead of the running boards, guard strips on each side of and close to the wires will be accepted. These strips to be not less than seven-eighths of an inch in thickness, and at least as high as the insulators.

Suitable protection on side walls may be secured by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes), and extending not less than five feet from the floor; or by an iron-armored or metal-sheathed insulating conduit sufficiently strong to withstand the strain to which it will be subjected, and with the ends protected by the lining or by special insulating bushings, so as to prevent the possibility of cutting the wire insulation; or by plain metal pipe, lined with approved flexible tubing, which must extend from the insulator next below the pipe to the one next above it.

If metal conduits or iron pipes are used to protect wires carrying alternating currents, the two or more wires of each circuit must be placed in the same conduit, as troublesome induction effects and heating of the pipe might otherwise result; and the insulation of each wire must be reinforced by approved flexible tubing extending from the insulator next below the pipe to the one next above it. This should also be done in direct-current wiring if there is any possibility of alternating current ever being used on the system.

For high-voltage work, or in damp places, the wooden boxing may be preferable, because of the precautions which would be necessary to secure proper insulation if the pipe were used. With these exceptions, however, iron pipe is considered preferable to the wooden boxing, and its use is strongly urged. It is especially suitable for the protection of wires near belts, pulleys, etc.

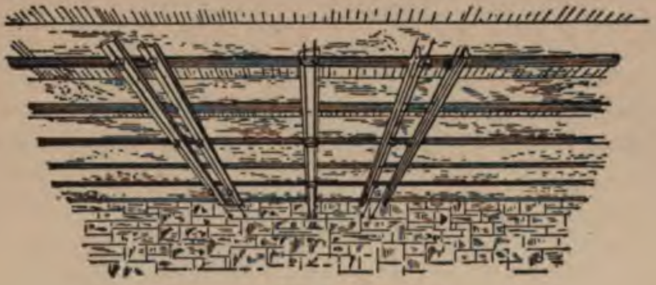


FIGURE 168.

f. When run in unfinished attics, or in proximity to water tanks or pipes, will be considered as exposed to moisture.

Figure 168 illustrates the meaning of the rule in regard to wires run along low ceilings.

Figure 169 gives the dimensions necessary for boxing wires on side walls. At the right, the sidewall protection consists of conduit; a junction box with the lower side knocked out is used to enclose bushings. When the cover is screwed on the wires are completely enclosed.

SPECIAL RULES.

For Open Work.

In dry places.

g. Must have an approved rubber or slow-burning weatherproof insulation (see Nos. 41 and 42.)

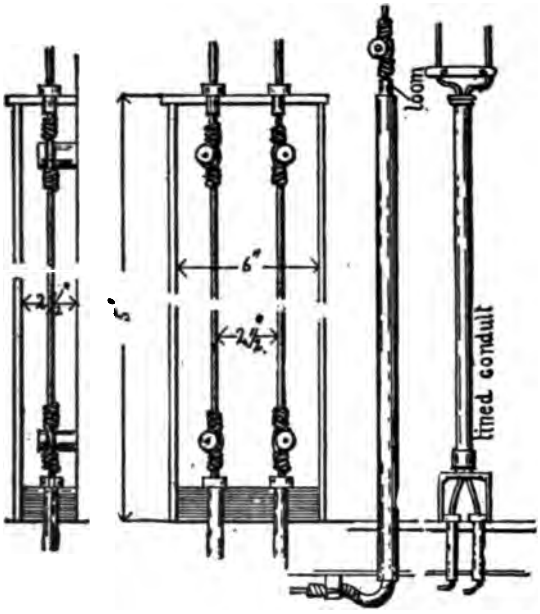


FIGURE 169.

A slow-burning weatherproof covering is considered good enough where the wires are entirely on insulating supports. Its main object is to prevent the copper conductors from coming accidentally into contact with each other or anything else.

Most of this wire as it is now made with the weatherproof braid on the outside, becomes sticky when exposed to the temperature found in most mill rooms in summer. This is objectionable, especially in linty places, as dust and flyings readily adhere to the wires, making it difficult to keep them clear. Under these conditions, the sweeping-down process generally results in loosening and deranging the wires in a short time. The weatherproof insulation is also very combustible, and when on the outside might allow fire to spread along the wires, especially if there were a number of wires near together, as stated in the note to No. 2 b. For these reasons it is considered preferable to place the weatherproof insulating next to the conductor, and the slow-burning braids on the outside. The outer surface should then be finished hard and smooth, similar to that on the old so-called underwriter wire. A wire insulated in this manner is not open to the objections noted above, and can also be more readily drawn into flexible tubing where the iron pipe construction described in the note to Section *e* is used.

h. Must be rigidly supported on non-combustible, non-absorptive insulators, which will separate the wires from each other and from the surface wired over in accordance with the following table:

Voltage.	Distance from Surface.	Distance between Wires.
0 to 300	½ inch	2½ inch
301 to 550	1 inch	4 inch

Rigid supporting requires under ordinary conditions, where wiring along flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed, the distance between supports should be shortened. In buildings of mill construction, mains of No. 8 B. & S. gage wire or over, where not liable to be disturbed, may be separated about six inches, and run from timber to timber, not breaking around, and may be supported at each timber only.

This rule will not be interpreted to forbid the placing of the neutral of an Edison three-wire system in the center of a three-wire cleat where the difference of potential between the outside wires is not over 300 volts, provided the outside wires are separated two and one-half inches.

Figure 170 shows different methods of running wires in buildings of mill construction. If the method shown at *a* is used, a few insulators should be placed here and there and the wires tied to them to prevent sagging. The arrangements shown at *b* and *c* are suitable for small wires on high ceilings.

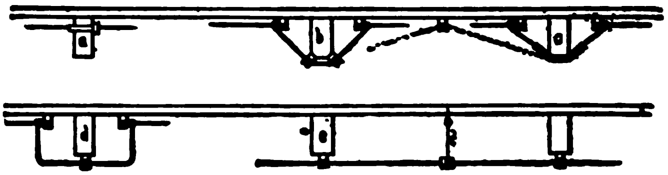


FIGURE 170.

The methods shown at *d* and *c* are sometimes used where there is no danger of interference. With long spans, supports as shown at *f* may be used.

In damp places, or buildings specially subject to moisture or to acid or other fumes liable to injure the wires or their insulation.

i. Must have an approved insulating covering.

For protection against water, rubber insulation must be used. For protection against corrosive vapors, either weatherproof or rubber insulation must be used. (See Nos. 41 and 44.)

j. Must be rigidly supported on non-combustible, non-absorptive insulators, which separate the wire at least one inch from the surface wired over, and must be kept apart at least two and one-half inches for voltages up to 300, and four inches for higher voltages.

Rigid supporting requires under ordinary conditions, where wiring over flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed, the distance between supports should be shortened. In buildings of mill construction, mains of No. 8 B. & S. Gauge wire or over, where not liable to be disturbed, may be separated about six inches, and run from timber to timber, not breaking around, and may be supported at each timber only.

In damp places the wires are often run on the under side of an inverted trough as shown in Figure 171. The main point of usefulness of such a trough lies in the fact that it prevents drippings from wetting the wires and insulators. Condensation will, however, keep insulators and wires wet nevertheless.

The trough, to be useful, should be put together with many screws, the butting edges of the boards having been first painted with a waterproof paint, with which, when finished, the whole trough is also painted inside and out.

Notwithstanding the rule given above, it would seem far better where practicable to use petticoat insulators and keep them much farther apart, even, if in order to do so a larger wire would be required. Each insulator, when wet, allows some current to leak over its surface and, therefore, the fewer we have the better so long as there is no danger of breaking wires. If splices are necessary in wet places they should be made quite a distance from insulators, the insulation of a splice being always weaker than that of the unbroken wire. Care should also be taken that the insulation of wires is not damaged through tying.

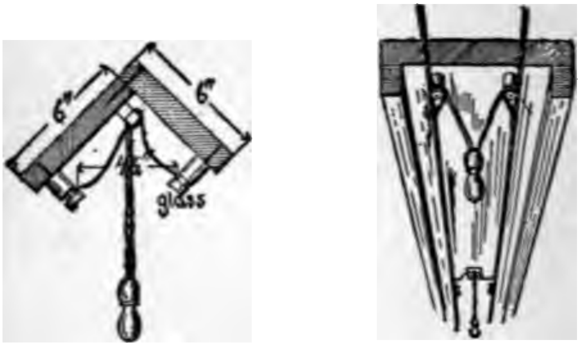


FIGURE 171.

Weather proof sockets are required by the rule and are best in such places when not subject to much handling. As these are, however, easily broken, brass shell sockets are often used. These are thoroughly covered with tape and compound so as to exclude all moisture and are very durable.

For Moulding Work.

l. Must have an approved rubber insulating covering (see No. 41).

m. Must never be placed in moulding in concealed or damp places, or where the difference of potential between any two wires in the same moulding is over 300 volts.

As a rule, moulding should not be placed directly against a brick wall, as the wall is likely to sweat and thus introduce moisture back of the moulding.

Figure 172 shows the dimensions of approved moulding.

Figure 173 shows the proper method of making a tap joint in moulding. This method brings the capping between the two wires of opposite polarity. Wires should never be crossed below the capping. If the exposed wire in Figure 173 is objectionable, part of the back of moulding may be cut out, or the wall back of the moulding may be gouged out as shown in Figure 174. This method must, however, never be used with other than walls or partitions of hardwood.

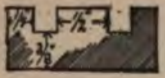


FIGURE 172.

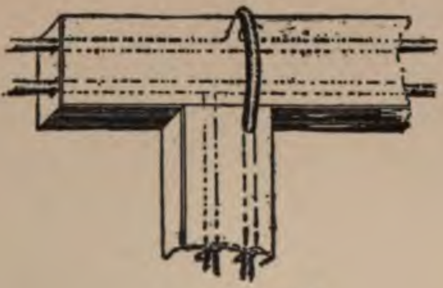


FIGURE 173.

Figure 175 shows proper method of tapping flexible cord to wires in molding. The whole cord should never be taken out of one hole in capping. There is always some chance of abrasion and joints are often poorly covered, so that there is always more likelihood of short circuits at this point.

Figure 176 shows how moulding should be fastened to tile ceiling. When toggle bolts are used, the nut should always be put on outside of capping (unless a very small one is used, or more than ordinary care is exercised). Many wiremen are careless and cut away the middle tongue too much, giving the nut a chance to work itself diagonally across it, so as to come in contact with both wires and, in time perhaps, cause short circuits. Although toggle bolts are mostly used, screws have been successfully used in tile. It is only necessary to first drill a hole of just the proper size for the screw to be used.

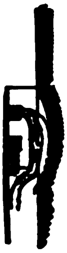


FIGURE 174.

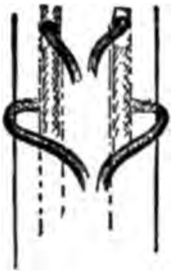


FIGURE 175.

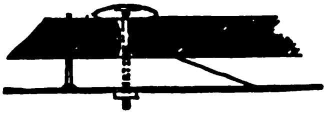


FIGURE 176.

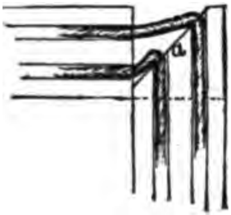


FIGURE 177.

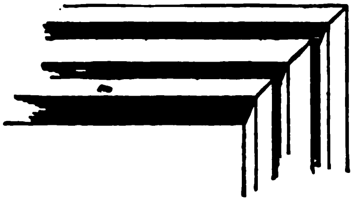


FIGURE 178.

A very rough, quick way of making a square turn with moulding is shown in Figure 177. One piece is cut entirely off along the line *a;* the pieces are then joined as shown and the capping hides the botch work. Such work will not be passed by inspectors if noticed. The proper way of fitting moulding is shown in Figure 178.

Figure 179 shows methods of running round corners. The saw cuts, a, b, c, etc., should be made with a fine saw and for short bends require to be close together. Bending is facilitated by wetting the moulding and if, before the moulding is put in place, the saw cuts are filled with glue, it will greatly add to the durability of the job. Screws or nails used in fastening the capping should pass through the moulding into the wall to get a firm hold.

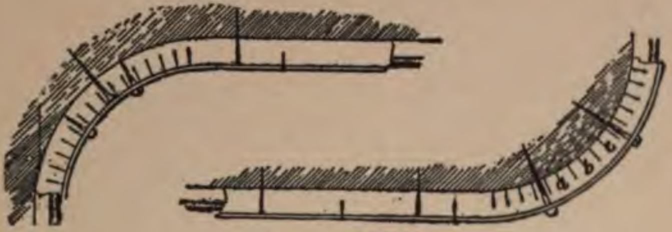


FIGURE 179.

For Conduit Work.

n. Must have an approved rubber insulating covering (see No. 47).

o. Must not be drawn in until all mechanical work on the building has been, as far as possible, completed.

p. Must, for alternating systems, have the two or more wires of a circuit drawn in the same conduit.

It is advised that this be done for direct-current systems also, so that they may be changed to alternating systems at any time, induction troubles preventing such a change if the wires are in separate conduits.

The same conduit must never contain circuits of different systems, but may contain two or more circuits of the same system.

If a single wire carrying alternating currents of electricity were run in iron pipe, there would be a very large drop in voltage. This drop is due to the fact that all currents while changing in strength generate a counter E. M. F. in their surroundings. This is particularly strong when the wires are surrounded by, or very close to, iron. If both wires are run in the same pipe, the current in one wire neutralizes that of the other and there is no trouble.

For Concealed Knob and Tube Work.

q. Must have an approved rubber insulating covering (see No. 41).

r. Must be rigidly supported on non-combustible, non-absorptive insulators which separate the wire at least one inch from the surface wired over. Must be kept at least ten inches apart, and, when possible, should be run singly on separate timbers or studdings. Must be separated from contact with the walls, floor timbers and partitions through which they may pass by non-combustible, non-absorptive insulating tubes, such as glass or porcelain.

Rigid supporting requires under ordinary conditions, where wiring along flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed, the distance between supports should be shortened.

s. When, in a concealed knob and tube system, it is impracticable to place any circuit on non-combustible supports of glass or porcelain, approved metal conduit, or approved armored cable must be used (see No. 24 *t*) except that if the difference of potential between the wires is not over 300 volts, and if the wires are not exposed to moisture, they may be fished on the loop system, if separately encased throughout in continuous lengths of approved flexible tubing.

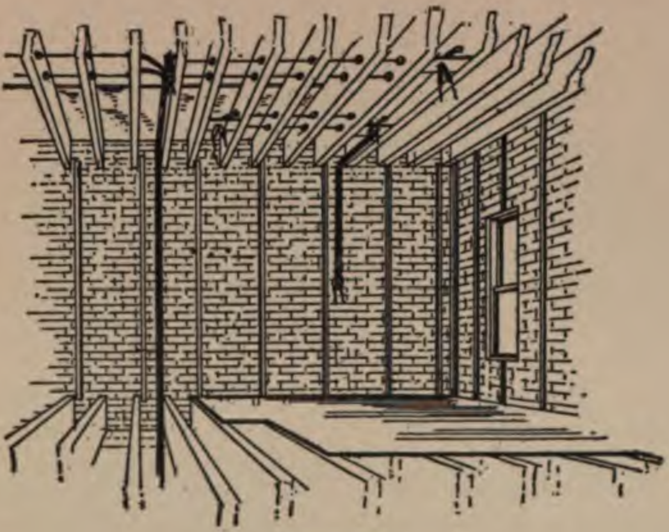


FIGURE 180.

An illustration of wiring on the loop system is shown in Figure 180. This system makes it unnecessary to have any concealed joints or splices. The amount of wire required is somewhat in excess of that required for tap systems, but this if often balanced by a saving in labor. Sometimes, however, the labor is also in excess of that required for tap systems. The main advantage of the system is that all joints and splices are always accessible. The figure also shows mixed knob and tube work and conduit work. Along the walls behind the furring strips there is seldom sufficient space to admit of knob and tube work and conduit must be used.

t. Mixed concealed knob and tube work as provided for in No. 24 s, must comply with requirements of No. 24 n to p, and No. 25, when conduit is used, and with requirements of No. 24 A, when armored cable is used.

u. Must at all outlets, except where conduit is used, be protected by approved flexible insulating tubing, extending in continuous lengths from the last porcelain support to at least one inch beyond the outlet. In the case of combination fixtures the tubes must extend at least flush with outer end of gas cap.

Figure 181 is drawn to illustrate fish work. Fish work is used in finished buildings, mostly, and is often very tedious and expensive. Hours are sometimes spent before wires can be brought through and often the effort is an entire failure. In combination work, as shown in Figure 167, there is usually little trouble, as there is the whole span between joists to run wires in. An effort to fish at right angles to the joists (when there are strips under joists) is more difficult, but often successful if the distance is not too great.

When there are two men the usual method of fishing is: One man takes a wire sufficiently long to reach from one opening to the other, and, after bending a small hook on one end in such a way that it will not catch easily on obstructions, pushes this end into one opening and, by twisting and working backward and forward, gradually forces it toward the other opening. At this opening his helper is stationed with a short wire, also provided with a hook, with which he must seek to catch the other wire when it comes near his opening. When the two wires come in contact, the larger one is drawn out and the conducting wires (encased in approved flexible tubing) are fastened to it and drawn through. The tubing should always be put on the wires before drawing in. If it is put on later there is much temptation to leave it as indicated at the right of the figure at *a*. This trick is quite common, but is very easily detected by inspectors, the wire at either end can easily be pushed in without pushing out at the other, as it would if the tubing were continuous. If the tubing has been taped to the wires this will be impossible, but either one of the tubings can still be moved without moving the other, which would be impossible in a job

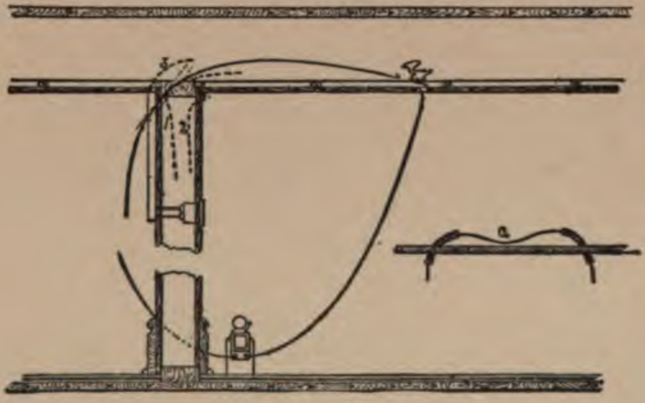


FIGURE 181.

properly done. The tubing must consist of one piece, and there must be only one wire in each tubing.

If one man is alone on a fish job, a handful of small wire is pushed into one opening in a manner which will allow it to spread out considerably. When the fish wire from the other opening comes in contact with it, it will indicate it by moving this wire, which can be seen by that left hanging out. A small fish wire is then used to draw out the long one. If the two openings are in different rooms and not visible, one from the other, a bell and battery can be used, as shown in the drawing. if there are no wire lath.

When wires are to be entirely concealed it is nearly always necessary to find a way through headers, timbers, etc., this can hardly be done without cutting holes in plaster. A method doing as little damage as any is shown at the top in Figure 181. A hole is bored through the 2×4, which will allow the wire, when job is finished, to continue downward as shown by dotted lines, 1 and 2. Such turns are seldom ever used with electric light wires on account of their size; they are more practicable with bell or telephone wires.

Where it is desired to keep wires from showing in a parlor, for instance, they can be fished from an adjoining room, as indicated by dotted line 3, where the wires are run down partition in moulding in closet and then through to switch, which is in the same room with the lights. Before undertaking a job of fish work it is well to look the whole building over carefully. There are often false walls along chimneys, especially at both sides of mantels, in which wires can be easily run from basement to attic.

Often it may be necessary to remove baseboards in order to find room for wires. When removing such boards never attempt to drive nails out, always break them off, if driven out they will usually split off parts of the board.

Soft wood floors can easily be taken up when necessary. Use a broad thin chisel and cut away the tongue on each side of the board to be taken up; the board can then be readily taken up. With double floors or with tightly laid hardwood floors, it is better to cut pockets in ceiling below.

For Fixture Work.

v. Must have an approved rubber insulating covering (see No. 46), and be not less in size than No. 18 B. & S. gage.

w. Supply conductors, and especially the splices to fixture wires, must be kept clear of the grounded part of gas pipes, and, where shells or outlet boxes are used, they must be made sufficiently large to allow the fulfillment of this requirement.

x. Must, when fixtures are wired outside, be so secured as not to be cut or abraided by the pressure of the fastenings or motion of the fixture.

y. Under no circumstances must there be a difference of potential of more than 300 volts between wires contained in or attached to the same fixture.

Rule 24 A. New Rule. Armored Cables.

(For Construction Rules see No. 48.)

a. Must be continuous from outlet to outlet or to junction boxes, and the armor of the cable must properly enter and be secured to all fittings.

NOTE—In case of underground service connections and main runs, this involves running such armored cable continuously into a main cut-out cabinet or gutter surrounding the panel board, as the case may be. (See No. 54.)

b. Must be equipped at every outlet with an approved outlet box or plate, as required in conduit work. (See No. 49 *l* to *o*.)

NOTE.—Outlet plates must not be used where it is practicable to install outlet boxes.

In buildings already constructed where the conditions are such that neither outlet box nor plate can be installed, these appliances may be omitted by special permission of the Inspection Department having jurisdiction, provided the armored cable is firmly and rigidly secured in place.

c. Must have the metal armor of the cable permanently and effectively grounded.

NOTE—It is essential that the metal armor of such systems be joined so as to afford electrical conductivity sufficient to allow the largest fuse or circuit breaker in the circuit to operate before a dangerous rise in temperature in the system can occur. Armor of cables and gas pipes must be securely fastened in metal outlet boxes so as to secure good electrical connection. Where boxes used for centers of distribution do not afford good electrical connection, the armor of the cables must be joined around them by suitable bond wires. Where sections of armored cable are installed without being fastened to the metal structure of buildings or grounded metal piping, they must be bonded together and joined to a permanent and efficient ground connection.

d. When installed in so-called fireproof buildings in course of construction or afterwards if concealed, or where it is exposed to the weather, or in damp places such as breweries, stables, etc., the cable must have a lead covering at last 1/32 of an inch in thickness placed between the outer braid of the conductors and the steel armor.

e. When entering junction boxes at all other outlets, etc., must be provided with approved terminal fittings which will protect the insulation of the conductors from abrasion, unless such junction or outlet boxes are specially designed and approved for use with the cable.

f. Junction boxes must always be installed in such a manner as to be accessible.

g. For alternating current systems must have the two or more conductors of the cable enclosed in one metal armor.

25. Interior Conduits.

(See also Nos. 24 n to p, and 49.)

The object of a tube or conduit is to facilitate the insertion or extraction of the conductors and to protect them from mechanical injury. Tubes or conduits are to be considered merely as raceways, and are not to be relied upon for insulation between wire and wire, or between the wire and the ground.

The installation of wires in conduit not only affords the wires protection from mechanical injury, but also reduces the liability of a short circuit or ground on the wires producing an arc, which would set fire to the surrounding material, the conduit being generally of sufficient thickness to blow a fuse before the arc can burn through the metal of the pipe. For this reason the wires should be entirely encased in metal throughout, both in the conduit and at all outlets. Another advantage derived from the use of iron conduit is the facility with which wires can be extracted and replaced in case a fault develops on any of them. The saving which this may mean in cases where the installation of new wires would necessitate the destruction of costly decorations can readily be seen. It must be rememberd that the arc or burn produced by a short circuit or ground is proportional to the size of the fuse protecting the circuit. If a large fuse, say 30 amperes, is used to protect a branch circuit and a ground or short occurs on this circuit, the wire may become fused to the pipe so that it cannot easily be pulled out. This is one reason why fuses should be as small as practicable. More than six amperes is seldom used on branch circuits, so that no larger fuse than this should ordinarily be used. The installation of wires in iron conduit also reduces the liability of lightning discharges entering a building as the pipe surrounding the wires offers great resistance to the passage of these sudden currents.

Conduit is classed under two general heads, lined and unlined. In both classes of conduit the same thickness of metal is required.

a. No conduit tube having an internal diameter of less than five eighths of an inch shall be used. Measurements to be taken inside of metal conduits.

This rule favors lined conduit insomuch that it requires the same pipe for lined and unlined, and allows a line conduit of less than five-eighths of an inch in diameter.

b. Must be continuous from outlet to outlet or to junction boxes, and the conduit must properly enter, and be secured to all fittings.

In case of underground service connections and main runs, this involves running each conduit continuously into a main cut-out cabinet or gutter surrounding the panel board, as the case may be (see No. 54).

When conduit is used every run of pipe must end in accessible outlet boxes. This box may be a cutout center, switch outlet, fixture outlet or a junction box. If a mixed form of wiring is used, where part of a circuit is run in conduit and the balance with some other form of construction, such as concealed knob and tube work, for instance, the conduit must in all cases enter the box and be firmly attached to it, as shown in Figure 182. Cases are sometimes found where the conduit is brought just to the box, but does not enter it, the wires being extended through holes into the box. This method of wiring is obviously wrong, as a wireman is apt to find

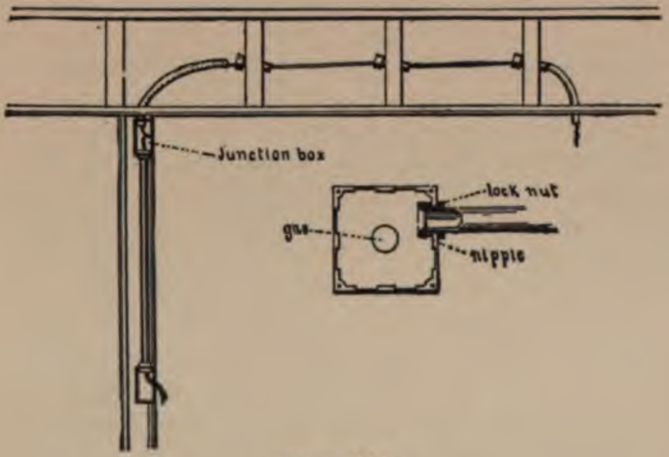


FIGURE 182.

if he ever has occasion to replace wires in such a system. The same holds true of cutout centers. Here also every run of conduit must enter the box. The conduit should not simply be brought to the sides or the back of the cutout center and the wires then carried to the cutouts in flexible tubing, but every conduit should enter clear into the box so that when the work is completed there will be no exposed wiring. In the case of main runs the conduit should enter the boxes and never be broken between the outlets. Sometimes it is necessary to install meters on the mains and the conduit is ended and the wires carried to the meters and then either extended in conduit or carried into the cutout center. The construction should be avoided. If a meter is to be installed near a cutout center, the main conduit should be carried into the box and the necessary meter loops then brought out. In this way the quantity of wire outside of conduits is reduced to a minimum. If a meter is to be installed in some location along the mains other than at the cutout center or service switch, a junction box should be provided and the meter loops brought out from that. This is shown in Figure 183, which also shows a cutout box as used with conduit systems.

c. Must be first installed as a complete conduit system, without the conductors.

As fast as the conduit is installed, the ends of the pipes should be closed, using paper or corks. This does away with the liability of plaster or other substances entering the pipes and causing trouble when the wires are to be pulled in. The conductors should not be pulled in until all the mechanical work on the building is, as far as possible, finished. When a conduit system is ready for the wires, the pulling in may be done in various ways. For short runs, all that is necessary is to shove the wires in at one opening until they come out at the other. If a run is too long to be inserted in this way, what is known as a fish wire can be used. The ordinary fish wire is a flat band of steel about 5/32 inch wide and 1/32 inch thick. This wire can be forced through any ordinary length of pipe. Ordinary round steel wire of about No. 12 or 14 B. & S. Gauge can also be used for fish wire, although this is not as good as the fish wire above described.

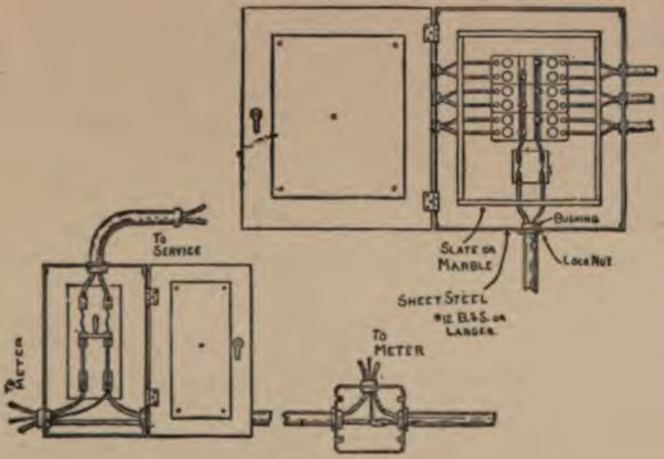


FIGURE 183.

The end of the wire is first bent back so as to form a very small hook or eye; this will enable it to slide easily over obstructions in the pipe and also make it possible should it stick somewhere to engage it with another fish wire provided with a suitable hook and entered from the other end of the pipe. This is very often necessary in runs having many bends. The fish wire, having been pushed through the pipe, is now fastened to the copper wire by means of a strong hook and the copper wire pulled into the pipe.

In pulling in the large size cables, it is often found advantageous to pull on the fish wire and at the same time push on the end of the cable entering the pipes. It is also well to remember that it is easier to pull down than to pull up, as, when pulling down, the weight of the cable assists. The use of soapstone facilitates the drawing in of the wires. The wire may either be covered with the powdered soapstone or the soapstone may be blown into the pipes. An elbow partly filled with soapstone is often found convenient for blowing the soapstone into the pipe, always blowing from the highest point.

d. Must be equipped at every outlet with an approved outlet box or plate (see No. 49 *l* to *o*).

Outlet plates must not be used where it is practicable to install outlet boxes.

In buildings already constructed where the conditions are such that neither outlet box nor plate can be installed, these appliances may be omitted by special permission of the Inspection Department having jurisdiction, providing the conduit ends are bushed and secured.

The object of an outlet box is to hold the conduits firmly in place, to connect the various runs of conduit so that they form a continuous electrical path to the ground, and to afford a fireproof enclosure for the joints, switches, etc. Outlet boxes are made in various designs to meet the requirements of the work on which they are to be used.

Where it is impossible to use an outlet box, an outlet plate can be used. These plates are fitted with set screws so that they hold the ends of the conduits firmly in position and make the metal of the system continuous. They do not afford a fireproof enclosure for the joints and for that reason should never be used when it is practicable to use an outlet box. If the conditions are such that neither an outlet box or plate can be used, special permission can be obtained from the Inspection Department having jurisdiction to omit them. In this case the conduits should be bushed at the ends and the pipes should be bonded together.

e. Metal conduits where they enter junction boxes, and at all other outlets, etc., must be provided with approved bushings fitted so as to protect wire from abrasion, except when such protection is obtained by the use of approved nipples, properly fitted in boxes or devices.

When a piece of conduit is cut with a pipe cutter, a sharp edge is left on the inside. This edge, if left on, would soon cut into the insulation of the wires. It should be removed by means of a pipe reamer. The bushing can now be screwed on as shown in Figure 182, a locknut having first been screwed onto the pipe. The locknut and bushings are then screwed up so that they are tight and form a good connection.

f. Must have the metal of the conduit permanently and effectually grounded.

It is essential that the metal of conduit systems be joined so as to afford electrical conductivity sufficient to allow the largest fuse or circuit breaker in the circuit to operate before a dangerous rise in temperature in the conduit system can occur. Conduits and gas pipes must be securely fastened in metal outlet boxes so as to secure good electrical connection. Where boxes used for centers of distribution do not afford good electrical connections, the conduits must be joined around them by suitable bond wires. Where sections of metal conduit are installed without being fastened to the metal structure of buildings or grounded metal piping, they must be bonded together and joined to a permanent and efficient ground connection.

That the metal in a conduit system should be permamently and effectually grounded is plainly evident when the hazards which are present with ungrounded or poorly grounded conduit are recalled. Until recently very little attention has been given to the matter of properly grounding conduits, but with the increased use the necessity of so doing has become very apparent. If the bare wire of one side of a system comes in contact electrically with the iron pipe, and if there is a ground on the other side of the system (and there always is with 3-wire systems) the conduit becomes a conductor. If the conduit system is so installed that every piece is in good electrical connection and the entire system effectually grounded no harm will be done except the blowing of a fuse. Conduit is installed in all kinds of locations. It may be in contact with a gas pipe, lead pipe, or run in a damp floor, or it may be run exposed where a person could easily come in contact with it. The effects that might result from a conduit so run should the conduit become alive are readily seen. Suppose that in the first case the conduit crosses the gas pipe at right angles, the area of contact would be very small and the effect of the current in a livened conduit crossing this poor contact would result in burning a hole in the gas pipe and igniting the escaping gas. Again, suppose the conduit run in a damp floor should become alive; the damp wood work, being a conductor, would soon char and the charred part would then readily ignite. With a system which is grounded, an exposed piece of conduit will usually only be alive for a very short time during the blowing of the fuse. Even if it remains permanently alive, current will not flow from it to the surrounding material, but will take the easiest path to ground; which is along the conduit. On the ordinary branch circuits, the various runs of conduit are bonded together through the outlet boxes and, in connecting the conduits to these boxes, care must be taken that they make good contact. In order to do this, the conduit should enter at right angles to the box and the enamel should be scraped away from the box so that the locknut and bushing make good electrical connection. The same thing should be done where the conduit enters the cutout box. The metal of the cutout box will bond together the various branch conduits and the main conduit. The main conduit should now be connected to some good ground, such as a water or steam pipe or metal work of the building. Never carry the ground wire to a gas pipe. The various branch conduits should also be grounded wherever possible, at and on metal beams over which they cross and at every gas outlet. The reason of grounding the gas pipe thoroughly at the gas outlets is to be sure of a good ground. The gas pipe is necessarily in contact with the outlet box at this point and any poor contact which might cause arcing must be avoided.

Strictly speaking, a conduit should be grounded with a wire equal to that used in the conduit. This can easily be done in the case of smaller circuits, but with the larger size mains it is a more difficult matter. No special device has as yet been designed for the ground wire connection, the usual practice being to take a number of good turns around the conduit and then solder the wire to the conduit and tape the joint. A better way would be to use a few T couplings on the system and to screw brass plugs to these and solder the ground wire to the plugs. Such couplings should be installed near outlets where they will not interfere much with fishing.

If the ground wire has to be run for any great distance, it should be installed as though it were at all times alive, and should be kept away from inflammable material. The method advised under 13 A for grounding wires should be used. Where a 3-wire system is used, the best ground obtainable is the neutral wire of the system. When a ground is made to the neutral wire, it should be made back of the fuses on the service switch; never make the connection with the neutral inside of the service switch.

g. Junction boxes must always be installed in such a manner as to be accessible.

h. All elbows or bends must be so made that the conduit or lining of same will not be injured. The radius of the curve of the inner edge of any elbow not to be less than three and one-half inches. Must have not more than the equivalent of four quarter bends from outlet to outlet, the bends at the outlets not being counted.

If more than four quarter bends are necessary, a junction box should be installed and the wires first pulled from one of the outlets to the junction box and then from the junction box to the other outlet.

Several methods are in use for bending conduit. With the lined conduit elbows and bends of various shapes can be obtained already bent, and it is much more satisfactory to use these, as considerable care must be exercised in making bends in order to keep the inside lining from coming loose from the pipe and causing trouble when pulling in. To prevent this a suitable spiral spring is sometimes inserted into the conduit before bending. Plumbers working with lead pipe often use coarse sand to fill the pipe before bending. This is more particularly useful with special conduits such as brass tubing, which is sometimes used in showcase or window work and classed with fixtures.

With unlined conduits the bending is a simple matter, although here also care must be taken to see that the conduit does not bend flat. In a good bend the pipe retains its circular form throughout the bend, while, if the bend is poorly made, the pipe will assume an oval shape, flattening somewhat at the bend. The smaller size conduits can be bent in a common vise. This is best accomplished by gripping the pipe in the vise and making a small bend, then moving the pipe for a slight distance and bending again, and continuing until the desired shape is obtained. Another method which can be used on small pipes is shown at *a* in Figure 184, using a three or four foot length of gas pipe or conduit with an ordinary gas pipe T on the end. This is run over the conduit and gives a sufficient leverage to make any bend.

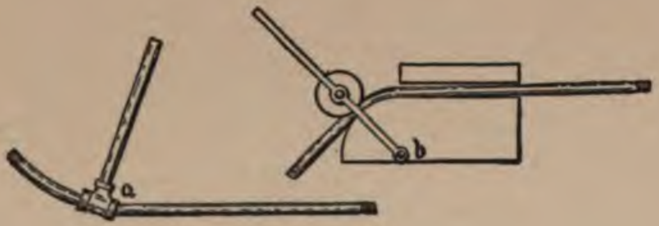


FIGURE 184.

A simple device used for bending conduits is shown at *b* in Figure 184. This is constructed of metal, the wheel being grooved to fit the pipe. A similar device, minus the wheel and lever, may be made up of two blocks of wood firmly fastened to a work bench. The pipe can be bent around this by hand.

For the larger size conduits, elbows can be obtained already bent. Connections between the various lengths of conduit are made with the ordinary gas-pipe couplings. When the conduit comes from the factory each length of pipe is provided with a coupling at one end. (This practice is now being discontinued, the couplings being left off.) This coupling should be removed and the end of the conduit reamed out. The reaming should always be done so that there is considerable metal left at the end of the pipe, and it should never be carried so far as to leave only a sharp edge. If a thread is to be cut, it is good practice to take a couple of turns with the reamer after this has been done. The coupling can then be screwed on. When making the connection, the pipes should be screwed into the coupling so that the ends just butt. Do not attempt to screw them too tight, or, in all probability, the thread on the end of the pipe will be turned in and close the opening. Figure 185, *a*, shows how a connection should be made. If lined conduit is not properly reamed and is screwed too tight, the opening is often entirely closed or forced inward, as shown at *b*.

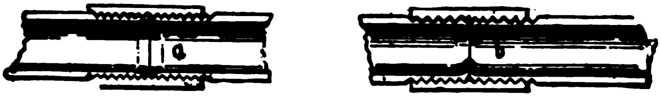


FIGURE 185.

It is often necessary, especially in making changes in old installations, to fit pieces between two pipes, neither one of which can be turned so as to draw them together. In such cases a long thread is cut on one piece of the pipe and the coupling run back on it, when the pipes are butted together the coupling is run over the two pipes, thus connecting them. A locknut may be run upon either pipe and used to keep the coupling in place.

In running conduits avoid as much as possible passing through bath-rooms and other places where plumbers are likely to run their piping.

When practicable, conduits should be run so they will drain, for instance, where crossing a room from one side bracket to another, it is better to run along ceiling than along the floor. Conduits will sometimes become quite moist inside from condensation. Where there is any likelihood of this the ends may be sealed.

26. Fixtures.

(See also Nos. 22 e, 24 v to x.)

a. Must when supported from the gas piping or any grounded metal work of a building be insulated from such piping or metal work by means of approved insulating joints (see No. 59) placed as close as possible to the ceiling.

Gas outlet pipes must be protected above the insulating joint by approved insulating tubing, and where outlet tubes are used they must be of sufficient length to extend below the insulating joint, and must be so secured that they will not be pushed back when the canopy is put in place.

Where canopies are placed against plaster walls or ceilings in fireproof buildings, or against metal walls or ceilings, or plaster walls or ceiling on metallic lathing in any class of buildings, they must be thoroughly and permanently insulated from such walls or ceilings.

Figure 186 shows insulating joints such as are used to insulate fixtures from the gas piping of buildings.

The object of an insulating joint is to prevent a ground on one fixture from causing trouble on other fixtures. If, for instance, one fixture in a building were in contact with the positive wire of the system and another in contact with a negative wire, and the two fixtures connected direct to the gas piping, the two contacts or grounds would form a short circuit, the current flowing from one pole along the gas piping to the other. This becomes impossible when the fixtures are insulated from the piping, or conducting parts of ceilings.

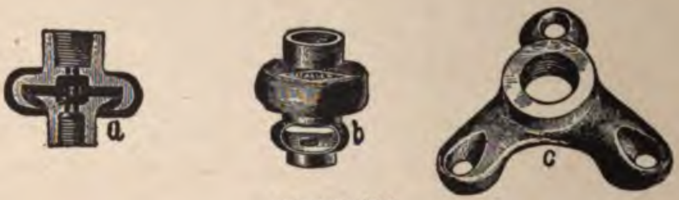


FIGURE 186.

Insulating joints are made in a variety of patterns. The one shown at *a* in Figure 186 is designed for use on a combination gas and electric fixture, and is made to allow the gas to pass through. Other forms, such as *b*, can be used on conduit work to connect to the stub in the outlet box, or on a gas outlet where it is desired to use the electric light only.

Insulating joints should be placed as close as possible to the ceiling, so that there will be a minimum of exposed pipe above the joint. If the gas pipe has been left long so that the insulating joint comes some distance below the ceiling, it is a good plan to protect the pipe above the joint either by using a porcelain tube which will fit over the pipe or by taping the pipe thoroughly. Flexible tubing is also sometimes used. See Figure 187.

In connecting the fixture, care should be taken that the extra wire usually left for making the joint is twisted around the pipe below the insulating joint, never above. If the wires at the outlet have been properly run, as shown in Figure 187, the flexible tubing will extend to the bottom of the insulating joint.

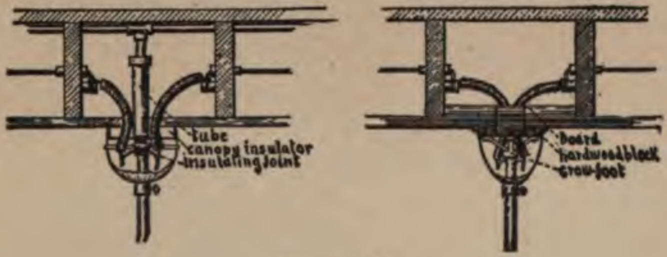


FIGURE 187.

When a straight electric fixture is to be installed on some grounded part of the building, a crowfoot, shown at *c*, Figure 186, can be fastened to the metal work and the fixture then connected with the insulating joint.

If the fixture is to be mounted on plaster, a hardwood block can be screwed to the walls or ceiling and a crowfoot screwed to this. The screws holding the crowfoot must not extend through the block. Such a case is illustrated at the right in Figure 187.

Before the plastering is put on, a board should be fastened between the joists, so that the wooden block may later be screwed on it. This is not absolutely necessary, as screws in lath will usually hold light fixtures. Heavy fixtures in old buildings can best be hung as shown at *b*, in Figure 188. This method is also used for ceiling fan motors. These moters must never be rigidly fastened, but should always be left free to swing and find their own centers.

In connection with open or moulding work, the canopies should always be cut out, so that the loom or moulding may enter them. On no account should wires be allowed to rest on sharp edge of canopy. See *a*, Figure 189.

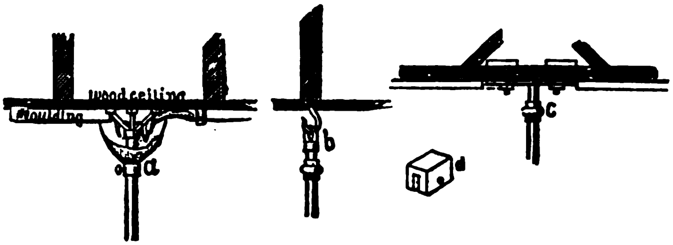


FIGURE 188.

Figure 188 illustrates at *c* how fixtures are fastened to tile ceilings, toggle bolts and a metal strip to which a piece of pipe is fastened being used.

Fiber is often used for the insulation of canopies from the ceiling. Figure 188 at *d* shows a bug insulator, which can be used for this purpose. A hole is drilled in the center of a small block of fiber, and it is then slotted lengthwise with a saw. A small dent is made in the upper edge of the canopy and the fiber block slipped on the edge, so that the small dent fits into the hole. If a hole is punched through the edge of the canopy, and a brass pin riveted in, a much better job is obtained. Short, thin strips of fiber, or a long strip riveted to the the inside of the canopy and left to project about one-eighth inch, are often used. These being placed on the inside of the canopy are much more sightly than the bug insulators. When a wooden block is used to fasten the fixture to the wall, the block may be made large enough so that the canopy will fit against it. The practice of fastening the canopy a short distance from the ceiling does not comply with the rule.

b. Must have all burs or fins, removed before the conductors are drawn into the fixture.

c. Must be tested for contacts, between conductors and fixtures, for short circuits and for ground connections before it is connected to its supply conductors.

Fixtures are always made up of gas piping and their construction is, therefore, very similar to conduit work.

Three tests should be made on each fixture before it is connected. If tests are not made until fixtures have been connected, it is often necessary to disconnect them again to determine whether a fault is in the fixture or in the wiring. Where there are several fixtures on one circuit and a short circuit should be discovered, it would also likely be necessary to disconnect several of them before the right one would be found.

A test for short circuit may be made, first, by connecting the two wires of a magneto to the two main wires at top of fixtures. If all sockets are properly connected and the wiring is clear, no ring will be obtained. If a ring is obtained, it indicates a short circuit.

Without changing connections each socket may now be tested for connections. While one man is operating the magneto, another may insert a screw-driver, jack-knife, or piece of wire into each socket in turn, thus connecting the two terminals and causing a ring of the magneto. Failure to obtain a ring would indicate an open circuit, which must, of course, be remedied.

The third test is made for grounds. To make it, the two fixtures wires are connected to one wire of the magneto and the other wire is connected to the metal of the fixture.

It is best to connect this wire to the iron piping, and not to the lacquered brass; the lacquer is often a very good insulator. If a ring is now obtained, it indicates that the insulation on a wire has been damaged, and that the bare wire is in contact with the fixture. This test can be made more thorough by working the accessible fixture wires back and forth during the test; sometimes, a damaged portion of wire is not in contact with the metal of fixture while lying upon the floor, but may be brought in contact with it when hanging.

Fixtures that have been connected to the circuit and provided with insulating joints can be individually tested for grounds, by connecting one wire of a magneto to the body of the fixture and the other, first to one, and then the other, of the circuit wires in the sockets. This test will detect a ground in a fixture without disconnecting it from the circuit.

In connecting sockets to fixtures, it is advisable to connect them so that all protruding parts, as keys or receptacles for lamps, be of the same polarity, that is, all connected to the same main wire. This also applies to reflectors, border lights for theaters, encased in metal, etc. This will not lessen the liability of such parts to ground, but lessens the chances of short circuits very much. Many shorts are brought about by the projecting brass lamp butts on fixtures being of opposite polarity. If they are of the same polarity, they will cause no trouble.

Special fixtures for show windows, etc., are often made up as shown in Figure 189. The construction shown at the left is more compact and neat, but requires more care in installing than the other, because of the edges of pipe in contact with the wires. If very long fixtures of this kind are installed, it is advisable to insert insulating joints as often as practicable, even if necessary to run wires around them.

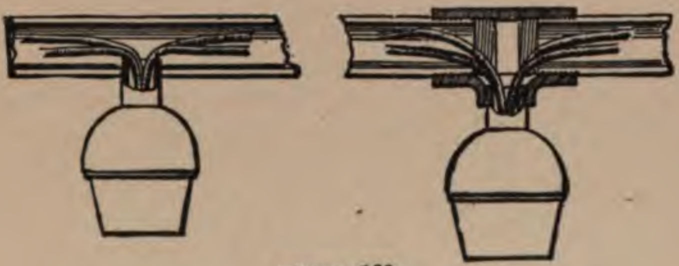


FIGURE 189.

27. Sockets.

(For construction rules, see No. 55.)

a. In rooms where inflammable gases may exist the incandescent lamp and socket must be enclosed in a vapor-tight globe, and supported on a pipe-hanger, wired with approved rubber-covered wire (see No. 41) soldered directly to the circuit.

In Firgue 190, *a* shows a vapor-tight globe suspended on a pipe-hanger, the construction of which complies with the requirements of this rule. If moisture is present it is well to seal the upper end of the pipe with compound.

b. In damp or wet places, or over specially inflammable stuff, waterproof sockets must be used.

Waterproof sockets should be hung by separate, stranded, rubber-covered wires, not smaller than No. 14 B. & S.

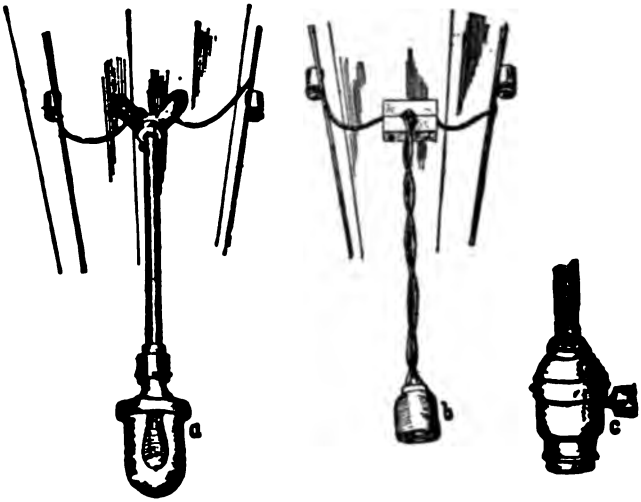


FIGURE 190.

gage, which should preferably be twisted together when the pendant is over three feet long. These wires should be soldered direct to the circuit wires, but supported independently of them.

Waterproof sockets are constructed entirely of porcelain and are not provided with keys, therefore the circuits to which they are connected must be controlled by switches. As a general rule these sockets are furnished with a short piece of stranded, rubber-covered wire extending through sealed holes in the top of the socket and the supporting wires are soldered to them. The method of suspending waterproof sockets varies with the conditions. Ordinarily, stranded rubber-covered wires of the proper length are suspended from single cleats as shown at *b*, in Figure 190, or, if the line knobs are large enough, the stranded wire may be supported from them. If the lamp is to be suspended only a short distance from the ceiling, where it will not be liable to be disturbed, it may be hung from two ordinary inch porcelain knobs, as shown in Figure 171. If cleats are used in a damp place for supporting the drop a half cleat must be provided back of the supporting cleat to give a one-inch separation, as required for wires in wet places.

28. Flexible Cord.

a. Must have an approved insulation and covering (see No. 45).

b. Must not be used where the difference of potential between the two wires is over 300 volts.

c. Must not be used as a support for clusters.

d. Must not be used except for pendants, portable lamps or motors, and portable heating apparatus.

The practice of making the pendants unnecesarily long and then looping them up with cord adjusters is strongly advised against. It offers a temptation to carry about lamps which are intended to hang freely in the air, and the cord adjusters wear off the insulation very rapidly.

For all portable work, including those pendants which are liable to be moved about sufficiently to come in contact with surrounding objects, flexible wires and cables especially designed to withstand this severe service are on the market, and should be used. (See No. 45 f.)

The standard socket is threaded for one-eighth-inch pipe, and if it is properly bushed, the reinforced flexible cord will not go into it, but this style of cord may be used with sockets threaded for three-eighths-inch pipe, and provided with substantial insulating bushings. The cable to be supported independently of the overhead circuit by a single cleat, and the two conductors then separated and soldered to the overhead wires.

The bulb of an incandescent lamp frequently becomes hot enough to ignite paper, cotton and similar readily ignitible materials, and in order to prevent it from coming in contact with such materials, as well as to protect it from breakage, every portable lamp should be surrounded with a substantial wire guard.

Flexible cord should be used only for drop lights which hang free in the air, or for desk lights or fan motors, where the cord is so installed that it is not liable to injury.

Cord adjusters should never be used where their use can be avoided and where they are installed should only be placed on lamps which will seldom need adjusting. The indiscriminate use of cord adjusters cannot be too strongly condemned as the constant rubbing soon destroys the insulation. At *c*, Figure 190, shows a brass socket threaded for ⅜-inch pipe, and which is designed to be used with portable cord. Care should be taken in making up these sockets to see that the knot under the head of the socket has a good bearing surface so that it will not pull through the larger bushing, these portables being very apt to be jerked about.

A lamp guard to be of any value should be so constructed that the bulb of the lamp cannot come in contact with anything outside of the lamp guard; it should also protect the lamp from any sudden jar. The design of the guard should be such that it can be firmly attached to the socket so it will not work loose and come in contact with the live butt of the lamp or projecting threaded portion of the socket.

e. Must not be used in show windows.

The great number of fires which have been caused by the use of flexible cord in show windows is sufficient argument against its use. Portable cord, or what is known as show window cord, should be used.

f. Must be protected by insulating bushings where the cord enters the socket.

g. Must be so suspended that the entire weight of the socket and lamp will be borne by knots under the bushing in the socket, and above the point where the cord comes through the ceiling block or rosette, in order that the strain may be taken from the joints and binding screws.

Special ceiling blocks or rosettes which facilitate the fastening of cords are on the market and should be used. In fastening the cord to sockets the end of the cord should be soldered. This does away with the liability of stray strands short circuiting on the shell of the socket and also affords a better and stronger contact under the binding screws. This soldering is best done by dipping the ends of the cord in melted solder. If a blow torch is used the small wires are very easily overheated and the soldering may do more harm than good. It is also well to tape the ends of cords, leaving only just enough bare metal to go under the binding screws; the tape will hold the end of the braid and will confine any ends of wires which do not happen to come under the binding screws.

29. Arc Lamps on Constant-Potential Circuits.

a. Must have a cut-out (see No. 17 *a*) for each lamp or each series of lamps.

The branch conductors should have a carrying capacity about 50 per cent. in excess of the normal current required by the lamp to provide for heavy current required when lamp is started or when carbons become stuck without overfusing the wires.

Figure 191 at the left gives a diagram of a constant potential arc circuit as generally used at present for enclosed arc lamps. Each arc lamp of this kind requires a pressure of 110 volts. A steadying resistance, R, is always placed in series with constant potential lamps, its object being to keep down the current while the lamp feeds. During the short time that the two carbons are together, the resistance of the lamp is so low that an enormous amount of current would flow were it not for this resistance. With most lamps this resistance is now installed in the hood. Since the rule requires a carrying capacity about 50 per cent in excess of the normal current for branch conductors, it would be well to provide this also for mains in such cases where groups of arc lamps

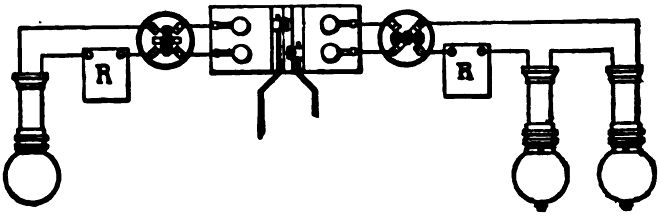


FIGURE 191.

are likely to be controlled by one switch and used together.

Figure 101 at the right shows a diagram of wiring for open arc lamps. Two lamps are usually run in series on 110 volts together with a steadying resistance. An open arc does not work well with a pressure higher than about 45 volts.

b. Must only be furnished with such resistance or regulators as are enclosed in non-combustible material, such resistances being treated as sources of heat. Incandescent lamps must not be used for this purpose.

c. Must be supplied with globes and protected by spark arresters and wire netting around the globe, as in the case of series arc lamps (see Nos. 19 and 58).

Outside arc lamps must be suspended at least eight feet above sidewalks. Inside arc lamps must be placed out of reach or suitably protected.

30. Economy Coils.

a. Economy and compensator coils for arc lamps must be mounted on non-combustible, non-absorptive insulating supports, such as glass or porcelain, allowing an air space of at least one inch between frame and support, and must in general be treated as sources of heat.

31. Decorative Lighting Systems.

a. Special permission may be given in writing by the Inspection Department having jurisdiction for the temporary installation of approved Systems of Decorative Lighting, provided the difference of potential between the wires of any circuit shall not be over 150 volts and also provided that no group of lamps requiring more than 1,320 watts shall be dependent on one cut-out.

No "System of Decorative Lighting" to be allowed under this rule which is not listed in the Supplement to the National Electrical Code containing list of approved fittings.

b. Incandescent lamps connected in series must not be used for decorative purposes inside of buildings except by special permission in writing from the Inspection Department having jurisdiction.

32. Car Wiring.

a. Must always be run out of reach of the passengers, and must have an approved rubber insulating covering (see No. 41).

33. Car Houses.

a. The trolley wires must be securely supported on insulating hangers.

b. The trolley hangers must be placed at such a distance apart that, in case of a break in the trolley wire, contact cannot be made with the floor.

c. Must have a cut-out switch located at a proper place outside of the building, so that all trolley circuits in the building can be cut out at one point, and line circuit-breakers must be installed, so that when this cut-out switch is open the trolley wire will be dead at all points within 100 feet of the building. The current must be cut out of the building whenever the latter is not in use or the road is not in operation.

d. All lamps and stationary motors must be installed in such a way that one main switch can control the whole of each installation—lighting or power—independently of the main feeder switch. No portable incandescent lamps or twin wire will be allowed, except that portable incandescent lamps may be used in the pits, the circuit to be controlled by a switch placed outside of the pit, and the connections to be made by two approved rubber-covered flexible wires (see No. 41), properly protected against mechanical injury.

e. All wiring and apparatus must be installed in accordance with rules for constant-potential systems.

f. Must not have any system of feeder distribution centering in the building.

g. The rails must be bonded at each joint with a conductor having a carrying capacity not less than that of a No. 2 B. & S. Gauge annealed copper wire.

h. Cars must not be left with the trolley in electrical connection with the trolley wire.

34. Lighting and Power from Railway Wires.

a. Must not be permitted, under any pretence, in the same circuit with trolley wires with a ground return, except in railway cars, electric car houses and their power stations, nor shall the same dynamo be used for both purposes.

HIGH-POTENTIAL SYSTEMS.

550 TO 3,500 VOLTS.

Any circuit attached to any machine or combination of machines which develops a difference of potential, between any two wires, of over 550 volts and less than 3,500 volts, shall be considered as a high-potential circuit, and as coming under that class, unless an approved transforming device is used, which cuts the difference of potential down to 550 volts or less.

35. Wires.

(See also Nos. 14, 15 and 16.)

a. Must have an approved rubber-insulating covering (see No. 41).

b. Must be always in plain sight and never encased, except where required by the Inspection Department having jurisdiction.

c. Must be rigidly supported on glass or porcelain insulators, which raise the wire at least one inch from the surface wired over, and must be kept about eight inches apart.

Rigid supporting requires under ordinary conditions, where wiring along flat surfaces, supports at least about every four and one-half feet. If the wires are unusually liable to be disturbed, the distance between supports should be shortened.

In buildings of mill construction, mains of No. 8 B. & S. Gauge or over, where not liable to be disturbed, may be separated about ten inches and run from timber to timber, not breaking around, and may be supported at each timber only.

d. Must be protected on side walls from mechanical injury by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes) and extending not less than seven feet from the floor. When crossing floor timbers, in cellars, or in rooms where they might be exposed to injury, wires must be attached by their insulating supports to the under side of a wooden strip not less than one-half an inch in thickness.

For general suggestions on protection, see note under No. 24 e. See also note under No. 18 e.

36. Transformers.

(When permitted inside buildings, see No. 13.)

(For construction rules, see No. 62.)

(See also Nos. 13 and 13 A.)

Transformers must not be placed inside of buildings without special permission from the Inspection Department having jurisdiction.

a. Must be located as near as possible to the point at which the primary wires enter the building.

b. Must be placed in an enclosure constructed of fire-resisting material, the enclosure to be used only for this purpose, and to be kept securely locked, and access to the same allowed only to responsible persons.

c. Must be effectively insulated from the ground, and the enclosure in which they are placed must be practically airtight, except that it must be thoroughly ventilated to the outdoor air, if possible, through a chimney or flue. There should be at least six inches air space on all sides of the transformer.

37. Series Lamps.

a. No multiple series or series multiple system of lighting will be approved.

b. Must not, under any circumstances, be attached to gas fixtures.

EXTRA-HIGH-POTENTIAL SYSTEMS.

OVER 3,500 VOLTS.

Any circuit attached to any machine or combination of machines which develops a difference of potential, between any two wires, of over 3,500 volts, shall be considered as an extra-high-potential circuit, and as coming under that class, unless an approved transforming device is used, which cuts the difference of potential down to 3,500 volts or less.

38. Primary Wires.

a. Must not be brought into or over buildings, except power stations and sub-stations.

39. Secondary Wires.

a. Must be installed under rules for high-potential systems when their immediate primary wires carry a current at a potential of over 3,500 volts, unless the primary wires are installed in accordance with the requirements as given in rule 12 A or are entirely underground, within city, town and village limits.

Fig. 192 shows what is known as the tree system of electric light distribution. The wires at the lowest floor must be of sufficient capacity to carry the total current. At each floor or succeeding center of distribution the size of mains may be reduced, suitable cutouts being provided as shown in the diagram. This system is not to be recommended, as it will result in great difference of potential between those branch circuits nearest the dynamo and those at the extreme end of the system. When the mains are fully loaded, the nearest lamps will either burn too bright or those at a greater distance will not be at candle-power.

This difficulty is largely overcome by the arrangement shown in Fig. 193. In connection with this wiring, compound dynamos may be so designed that the pressure at the center of distribution will remain nearly uniform for all loads. If, for instance, the wiring is arranged for a 3% drop, the dynamos may be over-compounded to that extent. The even illumination will compensate for the additional expense in wire.

Fig. 194 shows a two-wire circuit with seven lights controlled by a double-pole switch S, three lights controlled by a single-pole switch S′, and two lights not controlled by any switch.

Figs. 195 and 196 show three-wire circuits. Fig. 195 is arranged with double-pole switches, each switch completely disconnecting the wires controlled by it. In Fig. 196 only the two outside wires are broken, the neutral wire remaining intact. When single-pole switches are

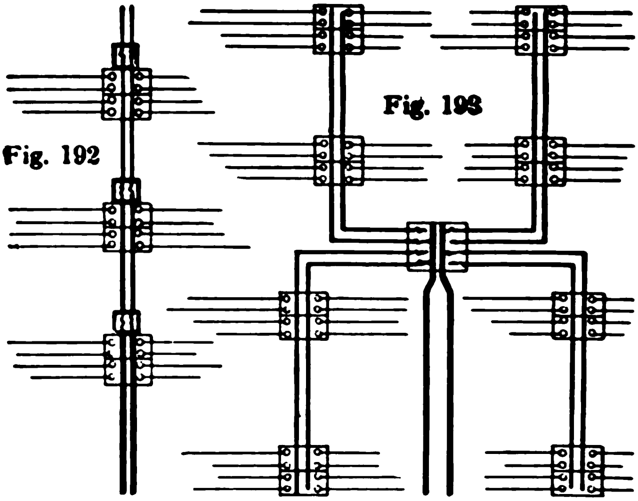


Fig. 192

Fig. 193

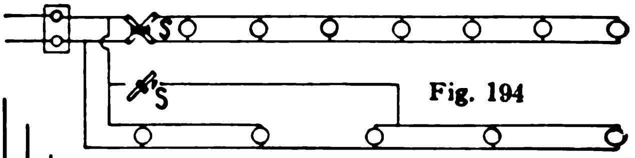


Fig. 194

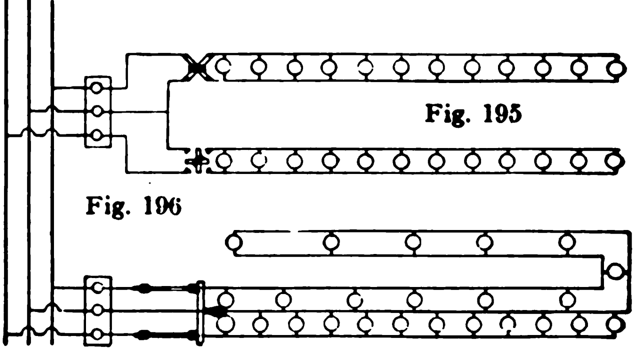


Fig. 195

Fig. 196

used in connection with three-wire systems, they should be placed on one of the outside wires, as the neutral wire is nearly always grounded. No switch must ever be connected so as to make it possible to break the neutral wire without also breaking the outside wires at the same instant.

Fig. 197 shows a double-pole method of controlling a circuit from two places.

In Fig. 198 a similar arrangement is shown acting single-pole and arranged at one end for a throw-over knife switch and at the other for a three-way snap switch.

By Fig. 199 the same result is accomplished, and in some cases this method may be more saving of wire than Fig. 78; but it cannot be used in connection with direct-current arc lamps, as the polarity may be reversed in turning lamps on and off.

Fig. 200 shows a method of controlling a circuit from any number of stations. Any number of double-pole switches, as shown in the center, may be cut into the line. Snap switches as shown in Fig. 201 may also be used in place of the throw-over knife switch.

By the system shown in Fig. 201 a circuit can also be controlled from any number of places. The single-pole switches remain in the center and other switches are added as required. With this arrangement polarities may also be reversed in turning lamps on and off.

Fig. 202 is known as an equal potential loop. This is useful on long lines where there is considerable loss; all lamps receive the same pressure and burn at the same candle-power.

Fig. 203 shows a method by which lamps may be used at full candle-power, or, by throwing the switch over, they may be used at half candle-power, two in series.

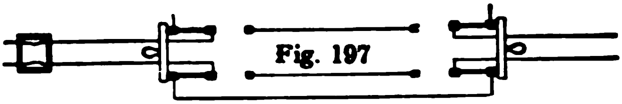


Fig. 197

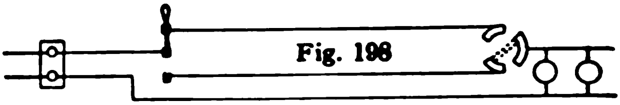


Fig. 198

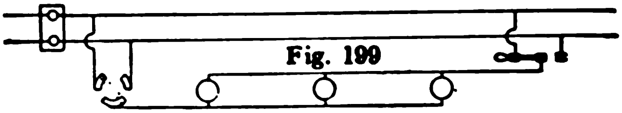


Fig. 199

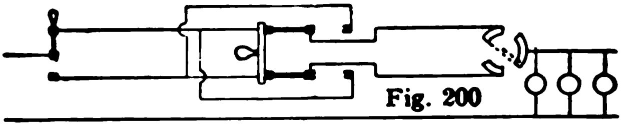


Fig. 200

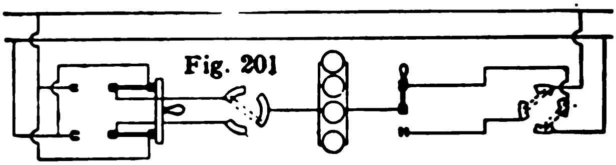


Fig. 201

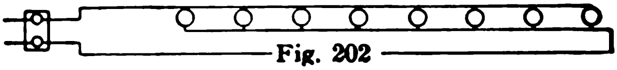


Fig. 202

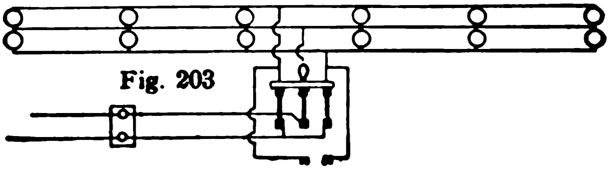


Fig. 203

Fig. 204 shows one switch arranged to burn either two, four or six lamps. When connected at 1, the two top lights alone will burn, at 2 the four bottom lights will burn alone, while by connecting 2 and 3 all six lights will burn.

Fig. 205 shows wiring arranged to provide a guest call for hotels or similar places. The bell 2 will ring and the lamp in series with it will burn only as long as the switch at the cutout remains closed. If the double-throw switch is thrown over, the bell 1 will continue to ring and the lamp will burn until the guest throws his switch over, or the party calling returns his to the original position.

In Fig. 206 the wiring for low-tension arc lamps is shown. Such lamps may be wired either in series or in multiple, the wiring being arranged to suit the kind of lamps used. With all lamps of this kind some resistance must be used. With lamps run in multiple it is usually provided with each lamp, and is generally built in with the lamp.

Fig. 207 shows a throw-over switch so arranged that only one lamp at a time can be used, one resistance answering for both. All switches used in connection with direct-current arc lamps must be arranged so that polarities cannot be changed by them.

Fig. 208 shows connections enabling one to burn either the two lamps at the right or those at the left, only two at a time being used. This arrangement requires the use of series lamps.

Fig. 209 shows a system of wiring which makes it possible to light all of the lamps in a building, not controlled by key sockets, from three different places at any time, even after they have been turned off by the occupants of rooms. In the top part of the figure one double-throw switch and one three-way snap switch are shown.

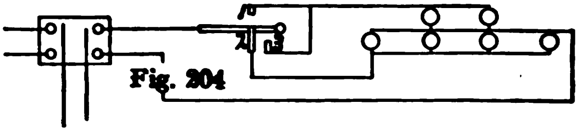


Fig. 204

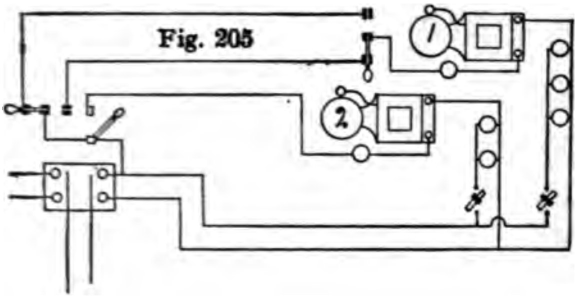


Fig. 205

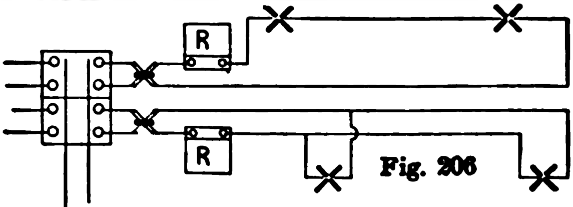


Fig. 206

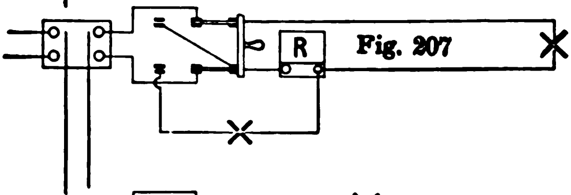


Fig. 207

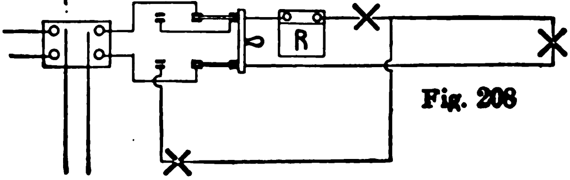


Fig. 208

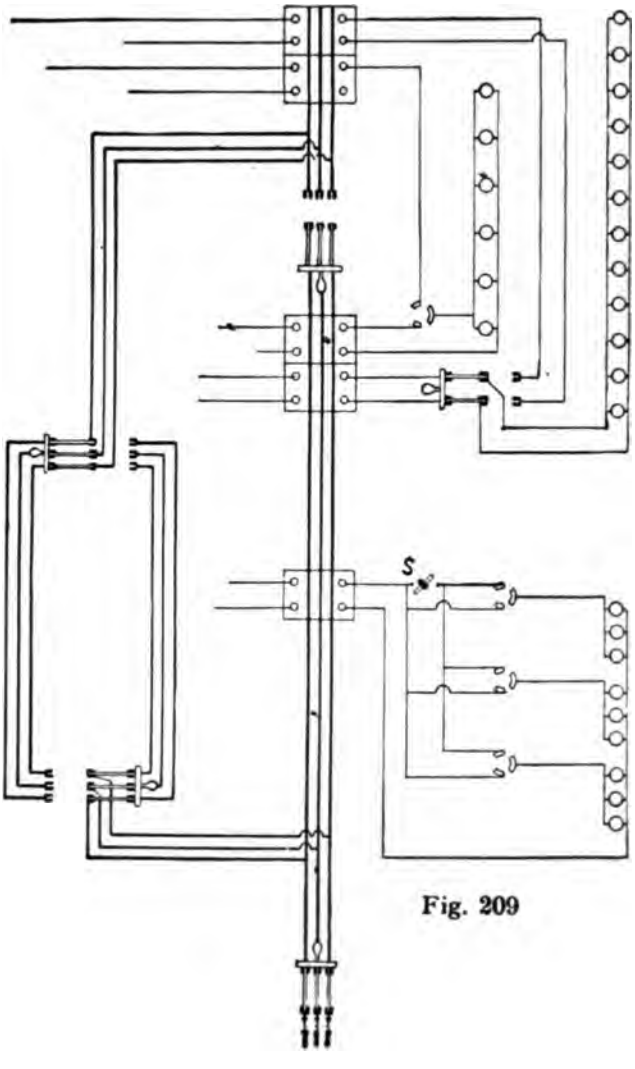


Fig. 209

Whenever, by either of these switches, the lamps are turned off, the switches make connection with the cutouts above, so that by throwing any one of the three knife-switches the lamps may be lighted again. In the lower part of the figure one circuit is arranged for the same purpose. By closing the single-pole switch S, all of the lights may be turned on at any time, excepting of course those that are turned off at the sockets. This arrangement is very useful in case of fire, or any emergency where it is desired to illuminate a whole house quickly.

Fig. 210 shows the wiring of a convertible system. By means of the three-wire switch, connections may be made to either a two or three-wire supply. With this system the middle or neutral wire should have as much carrying capacity as both outside wires, since when used with a two-wire supply it must carry the full load, while either of the outside wires need carry but half the current. Cutouts of the kind shown in group 1 should not be used in connection with this system. They are not very objectionable in straight three-wire systems, but when used in connection with two-wire systems the middle fuse must be doubled to carry the load. Such cutouts as are shown in group 2 are preferable. Great care is necessary when arc lamps are to be connected to such a system. They can be connected with one side of the neutral only, and this side must be arranged so that polarities are not reversed when the main switch is thrown over. Where arc lamps are used extensively the wiring used in Fig. 211 may be employed.

Fig. 212 shows incandescent lamps arranged in series. This plan of lighting is generally used in connection with street railway work. The figure shows 550 volt circuits

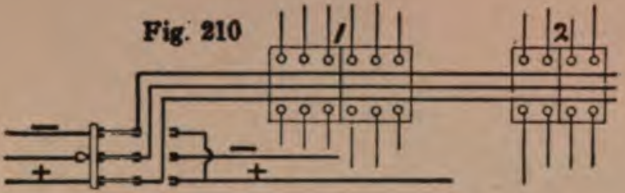


Fig. 210

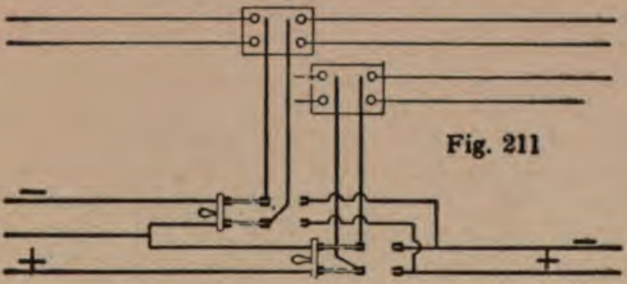


Fig. 211

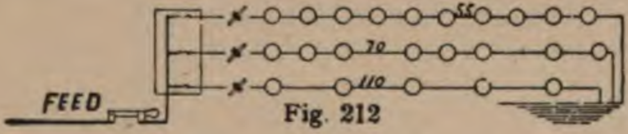


Fig. 212

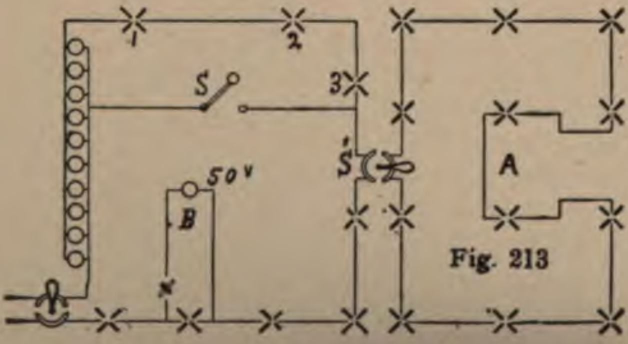


Fig. 213

provided with lamps of different voltage. Instead of the ground a return wire may be used.

Fig. 213 shows the wiring of a high-tension arc circuit. A group of incandescent lamps is also shown. When incandescent lamps are used in connection with arc lamps as shown there must be enough lamps in each group to take the current used by the arc lamps. The switch S controls the incandescent lamps and also the arc lamps 1, 2, 3, by simply short-circuiting them. The double-pole switch S′ controls the group A and is so arranged that when turned off this group is entirely disconnected. This is the only safe way of switching high-tension arcs, where they are merely short-circuited they are nearly as unsafe to handle as when burning. At B one incandescent lamp is shown controlled by a single-pole switch. When this lamp is burning it robs the arc lamp of as much current as it requires, the amount of current depending on the candle-power of the lamp. Incandescent lamps should be used on arc circuits only in an emergency and then only where there is little risk of fire.

Arc Lamps.

Fig. 214 shows the circuits of the improved Brush arc lamp. This lamp is used on constant-current direct-current systems. The current enters the positive binding post P and part of it goes through the resistance R to the carbon rods C, C, then through the carbons to the negative post N. The remainder of the current passes through wire *a* to the cut-out block C, O, but, as the cut-out is closed at first, the current crosses over through the cut-out bar to the starting resistance S, R, and to the negative side of the lamp: a part of this current, however, is shunted at the cut-out block through the coarse wire winding of the magnets M, M, and so to the upper carbon rod and carbons and out. The fine wire winding of the magnets M, M, is connected in the opposite direction to the coarse winding, and its attraction is therefore opposite. When the arc increases in length, its resistance increases, and consequently the current in the fine wire is increased. The attraction of the coarse wire winding is therefore partly overcome and the armature begins to fall. As it falls the arc is shortened and the current in the fine wire decreases. The fine wire of the magnets M, M, is connected in series with the winding of the auxiliary magnet M′. This magnet, which also has a supplementary coarse winding, does not raise its armature unless the voltage at the arc increases to 70 volts. The two windings connect at the inside terminal on the lower side of the auxiliary cut-out magnet and the current from the fine wire of the main magnets passes through both windings and then to the cut-out block and so to the starting resistance and out. If the main current is interrupted (as by the breaking of the carbons) the whole current of the lamp passes through the fine wire circuit. This will energize the auxiliary magnet M′ and close a circuit directly across the lamp through the coarse wire on M′ to the main cut-out and thence to negative terminal. When the main cut-out C, O, operates, the armature of the auxiliary cut-out falls because there is not sufficient current in that circuit to energize the magnet. This lamp is switched off by simply short circuiting it across N, N′. In all direct current arc lamps care must be taken to see that the current enters at the proper binding post, as the positive carbon burns away about twice as fast as the negative carbon. When a lamp is burning a small cup-shaped formation will be noticed at

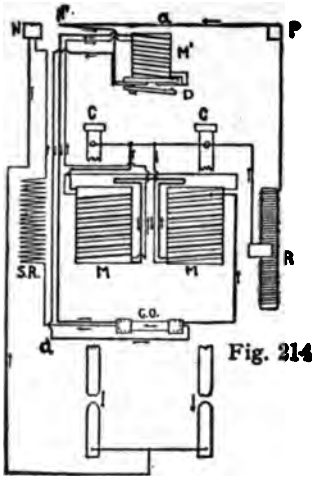


Fig. 214

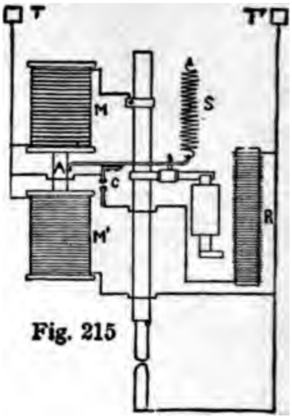


Fig. 215

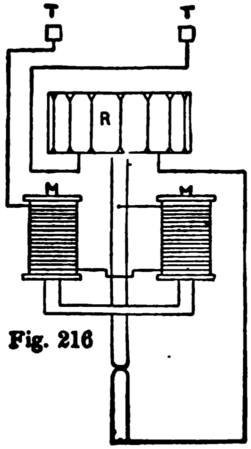


Fig. 216

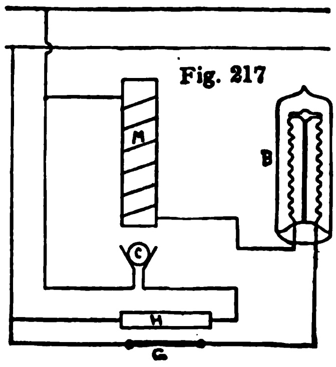


Fig. 217

the arc on the positive carbon and a small projection on the negative carbon. Lamps are generally connected so that the upper carbon is positive, and this hollow formation on the positive will throw the light downward. In this way it can be determined by the way the light is thrown as to whether a lamp is burning right side up or not.

Fig. 215 shows the circuits in a constant current alternating arc lamp. When the lamp is switched on current passes through the coarse winding of magnet M and then to the carbon rod and carbons and out at the other terminal. This energizes M and attracts the core A, thus raising the upper carbon and establishing the arc. The magnet M′ is wound with a great length of fine wire and opposes magnet M. As the resistance of the arc increases more current is sent around the fine wire winding of M′ and the core A and the carbon thus lowered. If for any reason, (breaking of the carbons, etc.) the resistance at the arc is greatly increased, the core A will be lowered until the two points of the cut-out C come in contact when the main current will pass through C and resistance R to the post T′. The resistance of R is in such proportion to M′ that just enough current is sent around M′ to keep the cut-out C closed. By means of the spring S the length of the arc may be adjusted. Tightening the spring increases the arc by requiring a greater amount of current to flow around M′ to lower the carbons.

Fig. 216 shows the winding of a constant potential alternating current arc lamp. R is a reactance or choking coil which is used to cut the voltage of the line down to that required by the lamp. This coil takes the place of the resistance coil in the direct current constant potential lamp. The current passes from the binding post T to the magnets M, M, and then to the upper carbon, from there to the lower carbon and then through the reactance coil and out at the other terminal. It will be noticed that this lamp has no shunt winding similar to the constant current lamp. This is unnecessary as the voltage at the terminals is practically constant. As the carbons burn away the current through M, M, is decreased, due to the increased resistance of the arc, and the armature is lowered, thus lowering the carbons. Direct-current, constant-potential lamps in general do not differ much from constant-current lamps of the same kind, except that no automatic cutouts can be used and that in order to put out the lamp the circuit must be opened. Constant current lamps require no extra resistance, while constant-potential lamps cannot be operated without some resistance to steady the current while the carbons are together.

Fig. 217 shows the diagram of a Nernst lamp. In the diagram, H is the heater which is made up of a winding of platinum wire on a porcelain tube; G is the glower which is composed of an oxide which at the ordinary temperature is of very high resistance but which when heated lowers its resistance considerably. The ballast B is made up of fine iron wire which when heated increases in resistance, thus tending to steady the current and keep the voltage over the glower as near constant as possible. When the lamp is started current passes through the heater H, gradually heating it and the glower, which is located directly below it. As the glower is heated current begins to pass through it and the cutout magnet M, until finally it becomes strong enough to attract the cutout C which opens the heater circuit. This circuit will then remain open as long as current is passing through the glower. These lamps are made in several sizes from one to six glower and they consume when burning 88 watts per glower. Each glower is equal in candle-power to three ordinary 16 candle-power incandescent lamps. When the lamp is started more current is used than when the lamp is burning, owing to the fact that the heater coils are in circuit. In the six glower lamp which takes when burning 2.4 amperes on 220 volts, the starting current rises to about 3.2 amperes. These lamps are at present used only on alternating current systems as the glower becomes blackened in a short time when used on direct-current systems.

Meters.

Fig. 218 shows the circuits in the two-wire Thomson recording wattmeter. One of the mains is connected through the winding M, M, which forms the fields of a motor. The armature of this motor is connected across the mains in series with a resistance R and the shunt field S. This shunt field is always in circuit, whether there is current used through the meter or not, and it is so arranged that it tends to start the motor. Its purpose is to overcome the friction of the armature so that the meter will register on very small loads. It will be noticed that the connection for the potential circuit is taken off the main at A. This is done so that the meter will register the current used in the potential circuit, and this is one reason why the generator must always be connected on the left side and the load on the right side of the meter. If this form of meter is fed from the wrong side it will run backward. In Fig. 218 it will be seen that if the feed were reversed (leaving polarities unchanged) the current through the fields would be in the opposite direction, while that through the armature would remain unchanged, hence the motor would be reversed. Used on direct-current this meter runs as a simple direct current motor and when used on alternating current, at each reversal of the direction of current the polarities of both the fields and armature are changed, and thus the motor will continue to run in the same direction because changing the direction of current in both the fields and armature of a shunt motor does not change the direction of rotation. There is no iron used in the construction of the motor and therefore no loss from heating.

Fig. 219 shows the two-wire meter for heavy loads. The circuits in this meter vary from the preceding one only in having but one main carried through the meter with a tap to the other main.

Fig. 220 shows the three-wire meter. The two outside wires (positive and negative) are carried through the meter, one through each field, and the armature is connected from one outside to the neutral. In some of the three-wire meters no neutral tap is used, the potential circuit being connected directly across the outside mains.

Fig. 221 shows a meter for a balanced three-phase line.

Fig. 222 shows a station meter for use on series arc lines.

Fig. 223 shows a meter used on switchboards to record the entire current passing through the bus bars.

Fig. 224 shows the circuits in the Gutmann wattmeter, This meter is used with alternating currents only and depends for its action on an aluminum disk, slotted in spiral lines, operated in joint action with a shunt laminated magnet coil S′ and a pair of series coils S, S. In the two wire meter the series coils are connected in series with one of the mains and the shunt coil is connected across the mains as shown in diagram. The loss in the shunt

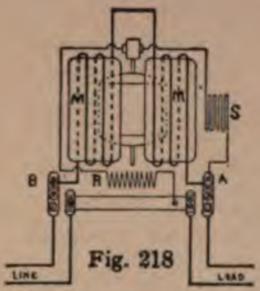


Fig. 218

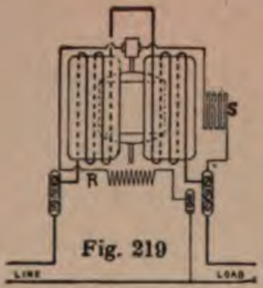


Fig. 219

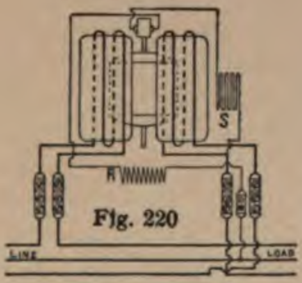


Fig. 220

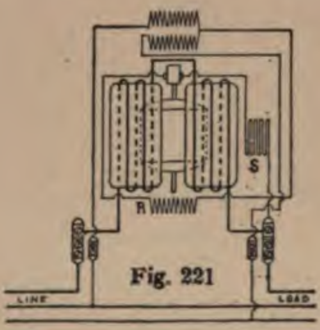


Fig. 221

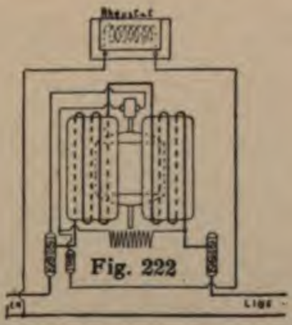


Fig. 222

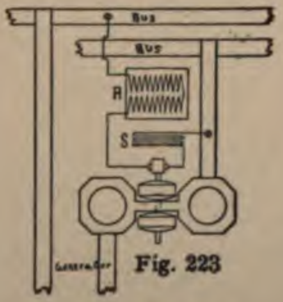


Fig. 223

coil does not exceed 1½ watts on the 110 volt 60 cycle meter and the drop in the series coil does not exceed ¼ of one volt on full load on the small size meters, and is proportionally less in the larger meters.

Fig. 225 shows the 200-250 volt meter. This meter has in series with the shunt coil a reactance coil R.

Fig. 226 shows the three wire meter. In this meter one of the outside mains is carried through one series coil and the other through the other series coil. No tap is taken to the neutral as the pressure circuit is connected across the mains as in the 200-250 volt meter.

Fig. 227 shows a meter for use on either 100 or 200 volt systems. The connection shown in the full lines is for 100 volts and the dotted for 200 volts. The reactance coil R is balanced to have exactly the same choke as the shunt coil.

In Fig. 228 the wiring of the three wire Edison chemical meter is shown. This is the meter first used on commercial work and depends for its action on the amount of zinc deposited on the plates in the solution. This meter is fast going out of use being displaced by the mechanical meters.

Fig. 229 shows a diagram of what is known as the Wright discount or demand meter. This meter is used in connection with a recording wattmeter to determine the maximum current which has been used during a given time. It is also used on circuits where it is desired to know the maximum current which has passed through the circuit. In the diagram B is a glass bulb connected to a tube U which is partly filled with a liquid. Around bulb B is wound a resistance wire which carries the main current. When current is flowing in this wire heat is generated and the air in the bulb is expanded thus forcing the liquid around tube U until it reaches the point

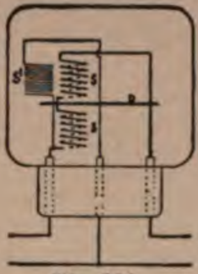


Fig. 224

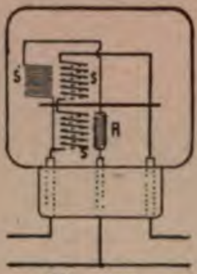


Fig. 225

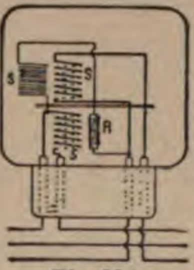


Fig. 226

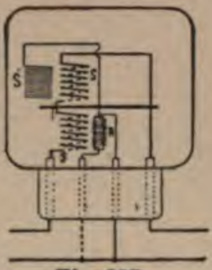


Fig. 227

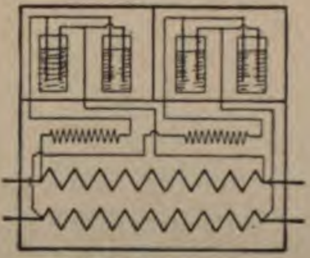


Fig. 228

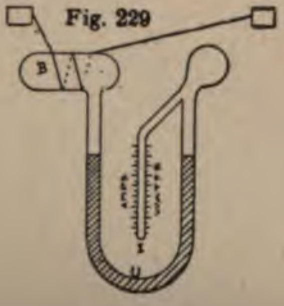


Fig. 229

where the tube U and I join, when it will flow into tube I. The amount of liquid in tube I will depend on the maximum amount of current which has passed through the resistance wire on bulb B. The scale back of tube I is graduated in amperes and watts. The meter is not effected by momentary increases in the current. If the maximum current lasts five minutes 80% will register; ten minutes, 95% will register; thirty minutes, 100% will register.

Transformers.

Fig. 230 shows the circuits in a single phase transformer.

Fig. 231 shows the circuits in a single phase transformer with a three-wire secondary. This transformer has the advantages derived from the use of three-wire distributing circuits, and is used where a large installation is to be connected, or where one large transformer feeds a set of secondary mains supplying a number of residences.

Fig. 232 shows the connections of a two-phase transformer with two separate secondaries, and Fig. 233 the two-phase transformer with a common return wire for the secondaries. Fig. 234 shows a three-phase delta connection, and Fig. 235 a three-phase star connection.

Figs. 236 to 243 show the connections used on the Packard Mark VI. transformers. The primary windings of these transformers are made in two sections, with leads brought out so that they may be connected either in series or parallel. When used on 2,000 volt systems the two sections are connected in series, and when used on 1,000 volt systems the two sections are connected in

Fig. 230

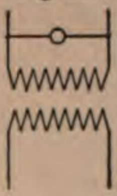


Fig. 232

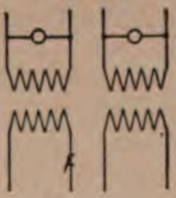
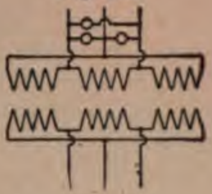


Fig. 234



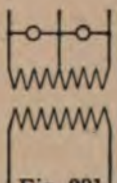


Fig. 231

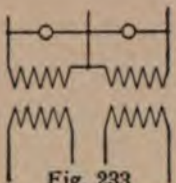


Fig. 233

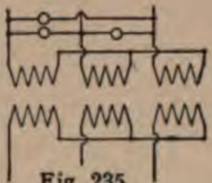


Fig. 235

PRIMARY.

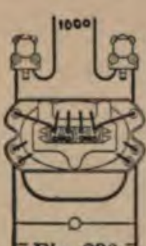


Fig. 236

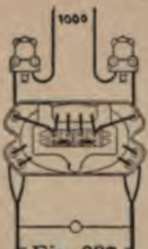


Fig. 237

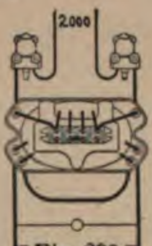


Fig. 238

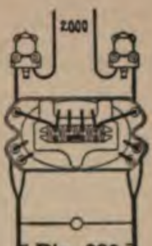


Fig. 239

PRIMARY

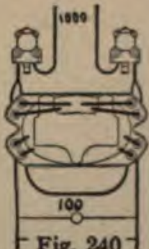


Fig. 240

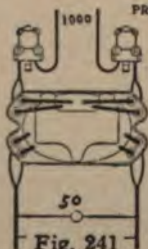


Fig. 241

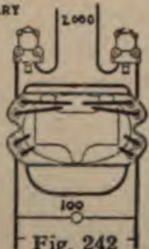


Fig. 242

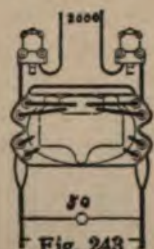


Fig. 243

parallel. These connections are shown in the diagrams, where, in Figs. 236 to 239, terminal blocks are used, and, in Figs. 240 and 243, the primaries are connected in the same way as the secondaries. The secondaries of these transformers are also wound in two sections, the same as the primaries, so that either 50 or 100 volts or 100 or 200 volts may be obtained, according to the type of transformer used. In Figs. 236, 237, 240, 241, the primary windings are connected in multiple, while in Figs. 238, 239, 242, 243, the primary windings are connected in series. The two secondary windings are connected in series in Figs. 236, 238, 240, 240, and in multiple in Figs. 237, 239, 241, 243.

Motors.

Fig. 244 shows the winding of a series motor for use on constant potential circuits. In this motor both the fields and armature are in series across the main circuit. The purpose of the starting box SB is to insert a resistance in series with the armature when starting, to prevent an excessive flow of current which would result were the main current thrown on fully with the armature at rest. To start the motor the main switch S is closed, and the arm of the starting box is moved gradually from one contact to another until it has reached the position where no resistance is left in circuit. It is then held by means of the small magnet M in this position until the current is cut off, or for some reason ceases to flow; when by means of a spring attached to it, the arm will fly back to its original position, thus making it impossible to throw the current on while all the resistance is out of the armature circuit. The small magnet M is connected directly across the mains, generally having a resistance in series with it to reduce the voltage on the winding.

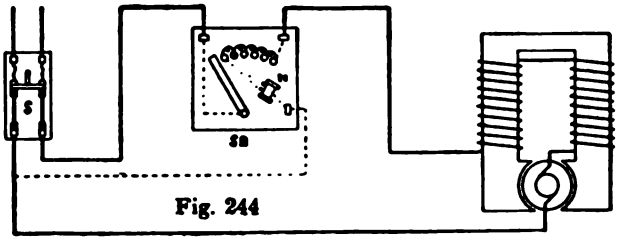


Fig. 244

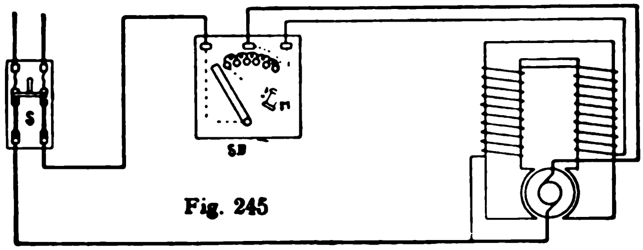


Fig. 245

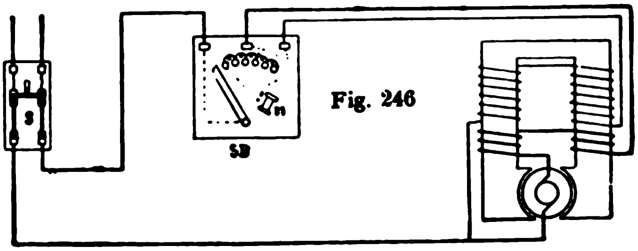


Fig. 246

This resistance is placed in the starting box, and is not shown in the drawing. In some motors the automatic coil M is connected in series with the main current, but in this case the variations in the current from no load to full load make its use unsatisfactory. The speed of a series motor varies with the load, decreasing as the load increases and vice versa. If the load is entirely removed the motor will run away, unless, as in the case of very small motors, where the ohmic resistance of the field and armature is sufficient to control it. This type of motor is also used on street car work, although in this case the starting box is replaced with a controller which, by varying the resistance or connecting the motors in series or multiple (where two motors are used), varies the speed. [See Fig. 252.] Reversing either the field or armature connections will reverse the direction of rotation. If the field and armature are both reversed the motor will run in the same direction. This motor is always protected from overload by a fuse or circuit breaker placed in the main circuit. Fuses are shown in the drawing on the motor switch.

Fig. 245 shows the winding of a shunt motor. The field and armature of this motor are placed in shunt across the main circuit. The starting box SB is placed in the armature circuit and performs the same service as in the constant potential series motor. The automatic coil of the starting box is connected in series with the field circuit. The speed of a shunt motor is practically constant, and for this reason this type of motor is extensively used. The motor is started in the same way as the series motor, and is protected from overload in the same way. If either the field or armature connections are reversed the motor will run in the opposite direction. The speed of a shunt motor may be varied by inserting resistance in either the armature or field circuit [See Fig. 247], or by shifting the brushes. It must also be remembered that the loss in the line in long runs feeding a motor will cut down the

P. D. at the armature, and this will decrease the speed as the load increases. To obviate this the size of wire should be chosen so that the drop in potential shall be as small as possible.

Fig. 246 shows the winding of a compound motor. In addition to the shunt winding on the fields an extra winding is added, which is in series with the armature. The starting box is connected in series with the armature, and the automatic coil M is connected in series with the shunt field as in the shunt motor. The series winding of these motors is connected in either of two ways, known as the cumulative or differential. The winding shown in the diagram is cumulative, the current in the shunt and series winding being in the same direction. In the differential winding the current in the series coil travels in an opposite direction from that in the shunt coil. Motors having the differential winding will maintain a more constant speed; for, as the load increases, the increased current in the series winding will partly neutralize the effect of the shunt winding and decrease the magnetism of the field, thus tending to increase the speed of the motor. On loads which have a constant variation, such as the planer, for instance, when, at the end of each stroke a great increase of load comes on, the differential motor is apt to spark badly. The cumulative motor will in the same case slightly decrease in speed at each stroke. The differential motor is not as efficient as the cumulative form from the fact that there is a waste of current due to the two fields opposing each other. Where motors are used in isolated plants the motor switches should be opened before the plant is shut down.

A number of different connections by which the speed of a motor may be varied or the direction of rotation reversed, are shown in Fig. 247. Where the three-wire system is in use the speed of a motor may be varied by using the three-wire double-throw switch, shown at the left of the diagram. With the switch thrown to the upper position the armature will obtain the full line voltage, and

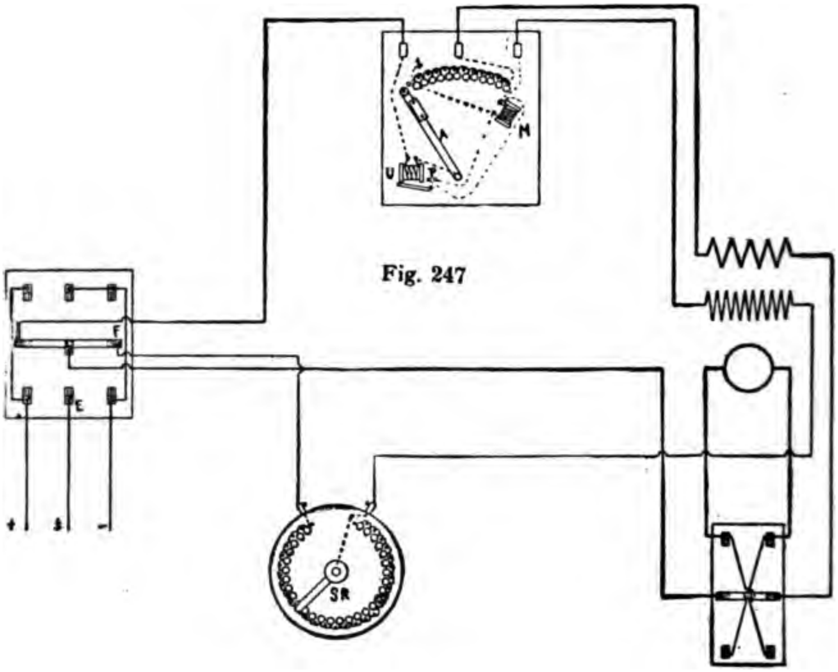


Fig. 247

with the switch on the lower position the armature will receive the voltage between the outside and the neutral; while the field will receive in both cases the full voltage of the line. In the 110-220 volt system the upper connection gives 220 volts and the lower connection 110 volts on the armature, the field receiving 220 volts. It is customary to use a three-wire single-throw switch to connect the service to the motor, this switch being placed in the line before the double-throw switch and being used whenever it is desired to shut down the motor entirely. The double-throw switch is only operated when the motor is at rest. In the upper part of the diagram are shown the connections of the Cutler-Hammer underload and overload starting box. With the movable arm A on contact shown in drawing no current will flow. If the arm is moved to contact 1 current will flow from the main through magnet U to the arm A, through all the resistance to the series field and armature and to the other side of the line. As soon as the movable arm has made contact with 1, current will also flow through the winding of magnet M and out to the shunt field and opposite side of line. The arm A is gradually moved to the right until it reaches the last contact, where all the resistance is cut out of the armature circuit. When it reaches this point the magnet M, which is energized, attracts the armature on the arm A and holds it in this position as long as current is flowing through the magnet. If the main supply were for any reason shut off, the magnet M would be de-energized, and the arm A (which is equipped with a spring) would fly back to the "off" position. This makes it impossible for the supply current to be momentarily cut off and then thrown on again while all the resistance is cut out of the armature circuit. In case the field circuit should open, by the breaking of a wire, for instance, the magnet M would be de-energized and the current cut off. When the motor is shut down by opening the motor switch, the arm A will not fly back until the speed of the motor has considerably decreased, owing to the fact that the motor is acting as a generator and sending current around the shunt field and coil M. The purpose of the magnet U is to protect the motor from any excessive rise in current, due either to a short circuit in the motor or to the throwing on of too heavy a load. With the normal current flowing through the winding of U, the armature below it will not be attracted; but if the current exceeds a certain amount the armature is attracted, and the winding of the automatic magnet M short circuited at the point P, thus demagnetizing M and allowing the arm A to fly back and shut off the current from the motor. The armature below magnet U is adjustable, so that it may be set to operate at whatever current is desired. Similar apparatus to the above may be used to regulate the speed of the motor by applying resistance in series with the armature, and thus cutting down the current; but in such case the apparatus is designed to carry the full current for an indefinite time. The automatic coil M is arranged to attract an armature which is connected to a pivoted lever, with a point at the other end which fits into a series of indentations on the lower part of arm A, and holds the arm squarely over the contacts in whatever position it may be placed for the required speed.

Strengthening the field of a motor will decrease the speed, and weakening the field will increase the speed. SR is a rheostat connected in series with the shunt field by means of which more or less resistance may be cut in series with the fields. Cutting in more resistance will reduce the current in the fields, and thus weaken them and increase the speed, and cutting out resistance will act in the opposite way.

The two-pole double-throw switch shown in lower right-hand corner may be used to reverse the direction of rotation of the armature. With the switch thrown to the upper contacts the current will enter the armature from the right-hand side, and with the switch thrown to the lower contacts current will enter on the left-hand side of the armature, thus reversing the direction of rotation. This switch should never be thrown while the motor is running, but should be thrown over while the armature is at rest.

Fig. 248 shows connections for the Cutler-Hammer printing-press controller, as used with a shunt motor. R is a resistance box generally in the larger size motors installed separately from the controller ,and connected to it by wire leads. The automatic coil M is connected in series with the field circuit, and when current is on attracts an armature (not shown in drawing) which is connected to a pivoted lever, the other end of which fits into a series of indentations on the lower end of the arm A and holds the arm in whatever position it may be placed. The arm A is made in two pieces, separated by an insulator so that the upper and lower parts are not in electrical connection. As the arm is moved to point 1, current from the mains enters the lower part of the arm and goes to the copper segment S. From there it is carried to the armature and back to the segment T. It then crosses the upper part of the arm to the contact 1 and through all the resistance in R and back to point 10 to the other side of the line. The field is simply connected across the mains through coil M. If the arm A is moved to point 1, the current will then flow through the armature in the opposite direction, thus reversing the direction of rotation. With the arm on contact 10 all the resistance is cut out of the armature circuit. This controller has ten variations in speed forward, and two backward. Fig. 249 shows the connections of this starting box when used with a compound motor.

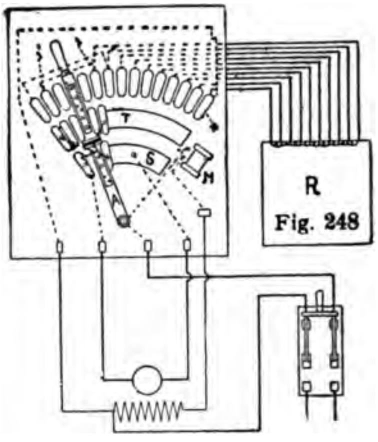


Fig. 248

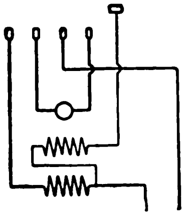


Fig. 249

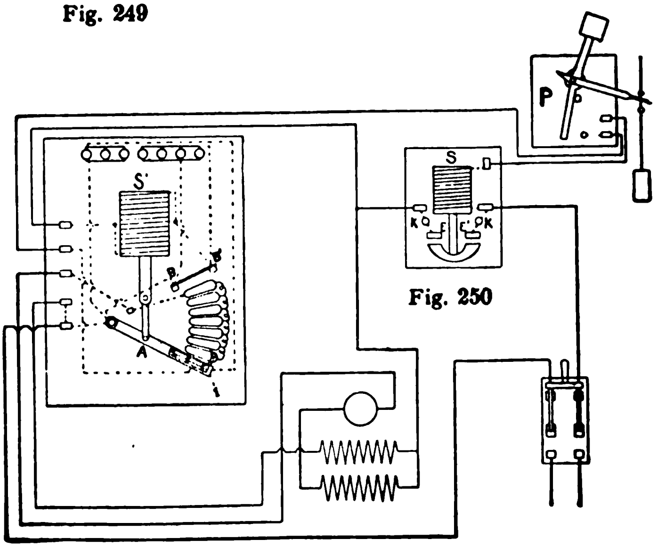


Fig. 250

In Fig. 250 are shown connections for the Cutler-Hammer self-starter used with a motor driven pump. The connections shown are for a compound motor. S is a solenoid connected across the mains through the switch P and the arm A of the self-starter. The current in this circuit varies from ¼ to 1 ampere, according to the size motor used. The switch P is controlled by a float in the tank, and is so arranged that it will close as the level of the water lowers and open again when the tank has become filled. This switch may be placed any distance from the motor. When the switch P closes, the solenoid S is energized, and the core, at the lower end of which is attached a copper contact piece, closes the contacts E, E′, thus allowing current to flow through the series field and armature of the motor and through all the resistance in the starter. At the same time, when E E′ is closed current passes through the solenoid S′ and through the small spring connecting contacts B B′. This energizes the solenoid S′ and draws up the core and arm A, thus gradually cutting resistance out of the armature circuit. When the arm reaches the upper contact, the circuit through the solenoid S′ is opened at B and the lamps thrown in series with it. This is done to cut down the current flowing through the solenoid, as less current is required to keep the arm in place than to move it over the contacts. The circuit from the small solenoid S is connected to the contact 1 so that when the arm A moves upward lamps are thrown in series with this circuit, to cut down the current in the solenoid S to that required to just hold it; so that, if for any reason the supply current is cut off, the contact E E′ cannot be closed until the arm A has moved to the lower point, where all the resistance is in the armature circuit. The number of lamps used varies with the size of motor. This same apparatus can be used with any air pump, or elevator in which the motor does not reverse, the switch P being replaced with the necessary switch. On the solenoid S the small magnets K are used to extinguish the arc at the break.

Fig 251 shows the connections of the Cutler-Hammer compound drum controller, this type of controller being used on printing presses, cranes and other work requiring a frequent change in speed and direction of rotation. In the upper part of the diagram is shown the drum laid out, the contact rings X, Y, Z, Y′, Z′ and W, and the segments below being mounted on a revolving drum, while the contacts 1 to 7 and B, A, SF, B;′ A′, SF′ and L are stationary, being supplied with fingers which make contact with the segments opposite as the drum is revolved. With the drum moved to the first point on the forward motion the rings X, Y, Z will come in contact with A, SF and 1 respectively, and the rings W, Y′ Z′ with B′, SF′ and L. Current will then flow from the + main through the series field to the resistance box R and through all the resistance to the point 1 of the controller. From 1 it passes to contact ring Z, and then through ring X and contact A to the armature and back to B′ and ring W to ring Z′ and contact L to the negative side of the line. As the drum is moved toward point 7 at each step, part of the resistance in series with the armature is cut out, until at 7 the armature and series field are connected directly across the mains. In the bottom of the controller are located two copper rings and a number of contacts, which are connected to their respective points in resistance box R. A small, movable contact shoe short-circuits rings 11 and 17, while the controller is moved from points 1 to 7, thus allowing current to pass from the positive side of the line to 17, on to 11, and then through

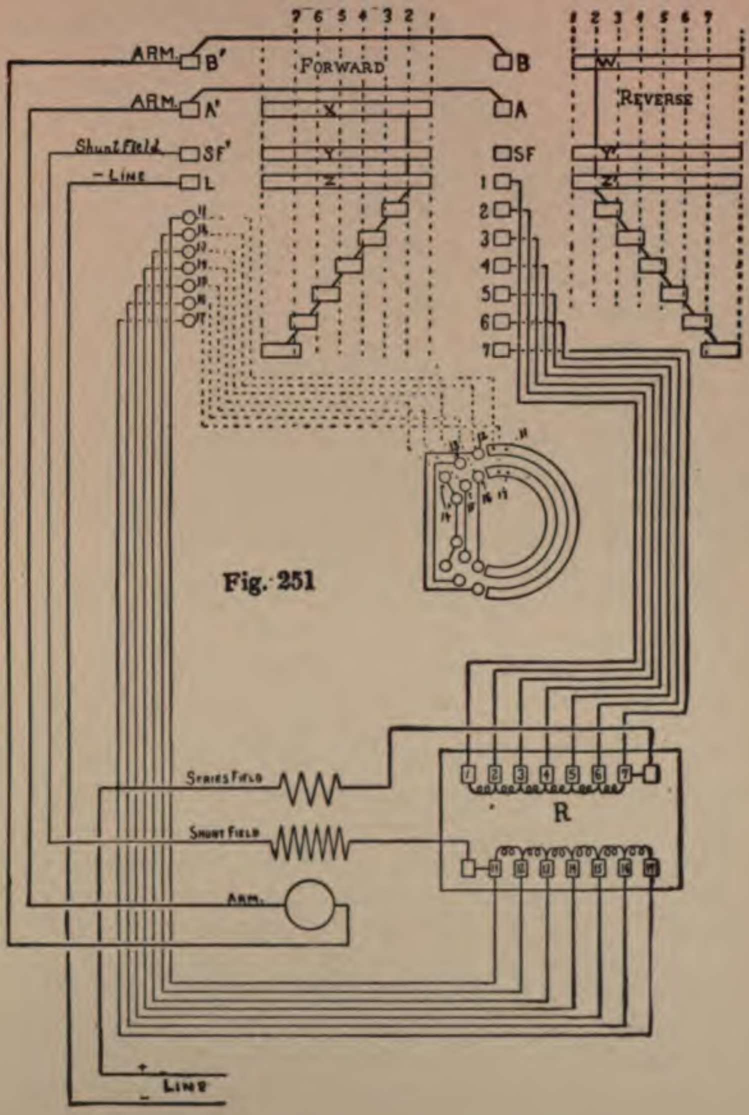

7 6 5 4 3 2 1
1 2 3 4 5 6 7
ARM.
B'
FORWARD
B
W'
REVERSE
ARM.
A'
X'
A
Shunt Field
SF'
Y'
SF
Y'
-Line
L
Z'
Z'
1
2
3
4
5
6
7
11
12
13
14
15
16
17
Series Field
Shunt Field
ARM.
R
+
Line
-

Fig. 251

the shunt field and out to bar Y′ on controller and to negative side of line. As the drum passes point 7 the contact shoe connecting 17 and 11 will then connect 17 and 12, thus cutting the resistance between points 11 and 12 in the resistance box R in series with the field and increasing the speed of the motor. As the controller is moved still further, more resistance is cut in and the motor has obtained its highest speed. If the drum is moved to 1 on the reverse motion the same connections are made with the exception of the armature. In this case current from contact 1 passes to ring Z′ and then to B and armature, this causing current to flow in the opposite direction in armature and reversing the direction of rotation. In printing press work a stop is used which allows the reverse motion to take in two contacts only, thus limiting the reverse to two speeds.

Fig. 252 shows the connections of the General Electric K2 street car controller. This controller is of the series parallel type, and varies the speed of the car by connecting the motors first in series and then in parallel, suitable resistance being used to give a gradual starting current. In Fig. 253 are shown the various connections between the rheostat and motors obtained at the different points of the controller. In the upper left-hand corner the drum of the controller is laid out. T, R1, R2, etc., are stationary contacts with fingers which make contact with the various segments on the drum as it is revolved. At the right of the controller is the reversing switch, by means of which the car can be made to go in either direction. The reverse switch is also a drum on which are placed two sets of contacts, these making connection with the stationary points F2, AA2, etc., as the drum is revolved. If the controller drum is moved to point 1, the current from the trolley wire enters at T, then to

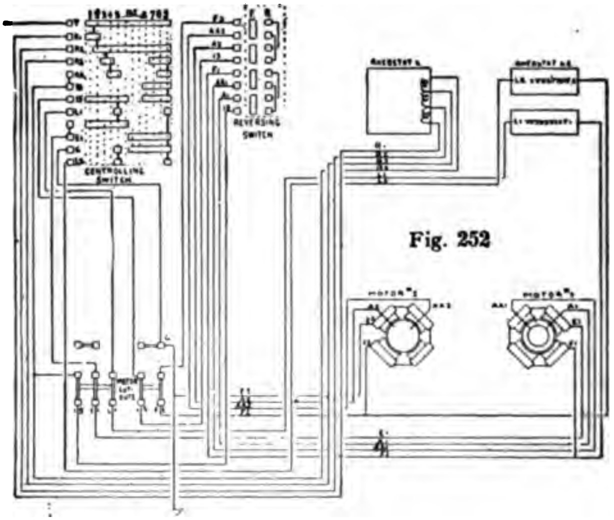


Fig. 252

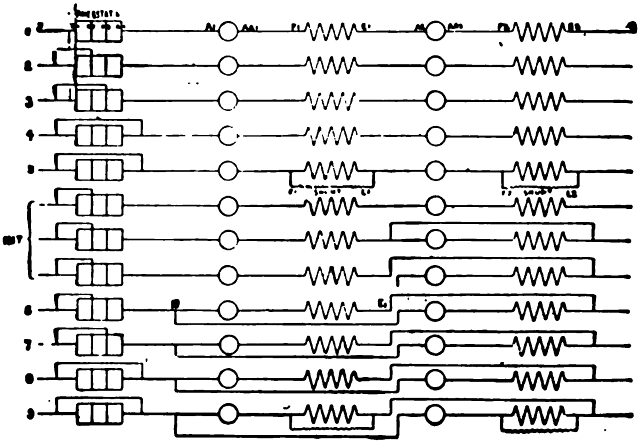


Fig. 253

segment on drum opposite T. From there it passes to contact R1, then to rheostat K, though all the resistance to the point 19 on the reverse switch. With the reversing switch on F it will then pass to A1, through the armature of motor No. 1 back to AA1, on the reverse switch and through field of motor No. 1 to the point E1 on the controller. From E1 it passes to the point 15 by means of segments on the drum, and to 15 on the reversing switch and to armature of motor No. 2 back to AA2 on the reversing switch, and to the field of motor No. 2 and back by means of E2 to the ground. The two motors are now connected in series with all the resistance in rheostat K in series with them. This is shown in 1 of Fig. 253.

As the controller is moved to points 2 and 3, part of the resistance in rheostat K is cut out, until at 4 the two motors are running in series with no resistance. At point 5 the fields of both motors are weakened by shunting them around the resistances in rheostat K2, thus further increasing the speed. The points between 5 and 6 are used to change the connections from series to multiple. At point 6 the motors are in multiple, in series with part of the resistance in K. At points 7 and 8 part of this resistance is cut out, while at 9 the motors are connected in multiple with the fields weakened. In case it is necessary to cut out one of the motors, this may be done by means of the switches shown below the controller. If the switch at the left hand is thrown to the upper contacts, motor No. 1 will be short-circuited. Throwing the other switch up short-circuits motor No. 2. When one of the motors is cut out, a stop comes into play which allows the controller to move over the first five points only. If this were not done and the controller moved to point 6, the trolley would be directly connected to ground through the rheostat K. This can be seen by reference to 6 in Fig. 253, where cutting out motor No. 1 short-circuits 19 and E1. The car should never be run with the resistance in rheostat K in circuit, therefore points 4, 5, 8 and 9 only should be used for any great length of time.

The speed of a constant current series motor varies with the load, decreasing as the load becomes greater and increasing in speed as the load becomes lighter. If the load is entirely removed the motor will run away. No satisfactory method of winding has been devised which would make these motors self-regulating, so that if the motor is to be used on a varying load some mechanical device must be employed to regulate the speed.

In Fig. 254 the arm A moves over a series of contacts which are connected to different points of the field winding. This arm may either be moved by hand, or, as is more common, connected to a centrifugal governor. As the load on the motor increases, its speed will slightly decrease, thus decreasing the speed of the governor and moving the arm upward. This cuts out part of the field wind and speeds up the motor.

In Fig. 255 the arm A moves over a number of contracts which are in connection with the resistance wire R. Current coming from the left-hand main passes through the lower part of the resistance R and is shunted at the arm A, part of it passing through the remaining resistance and part of it going to the motor. By changing the position of the arm, more or less current can be sent through the motor, the greatest amount passing through it when the arm is at the lowest contact. The arm may either be moved by hand or used with a centrifugal governor, as described in the preceding paragraph. It will be seen that this method is not very efficient, as a great deal of energy is consumed in the resistance wire.

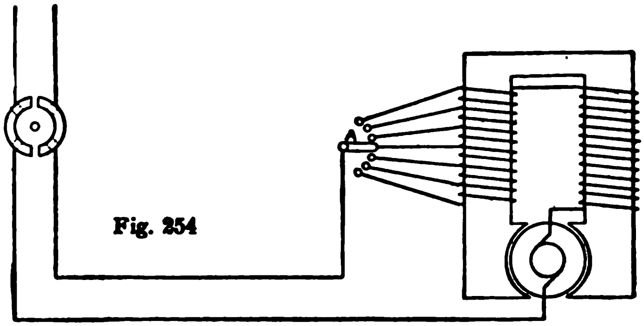


Fig. 254

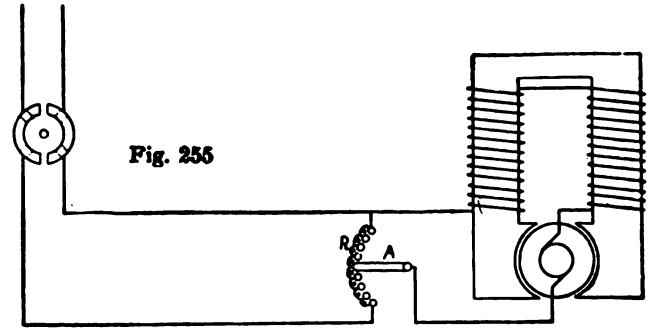


Fig. 255

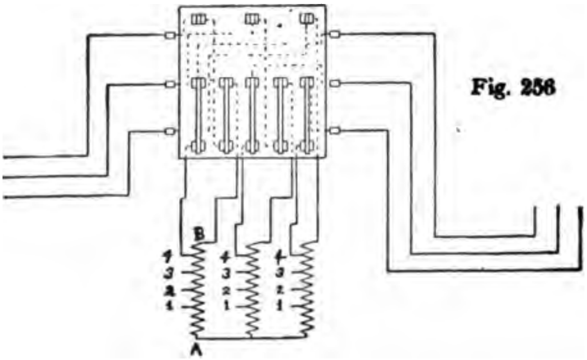


Fig. 256

There are a number of other methods used for constant current series motor regulation, but they are mostly variations of those shown. This type of motor is fast being replaced by the constant potential motor. Fuses are never used on these motors, as the current is always the same, and the switch used to start and stop the motor closes the main line when it opens the motor circuit. The ordinary snap switch cannot be used.

Fig. 256 shows the connections of the General Electric Company's compensator used in starting three-phase motors. This apparatus consists of three coils wound on laminated iron cores forming a transformer in which one wire is used for both primary and secondary, and works on the principle that, if an alternating current is sent through a coil of wire, and a tap taken from some intermediate point in the winding, the voltage between the tap and the end of the coil will be less than the full voltage supplied, depending on the position at which the tap is taken off. In the diagram suppose that the difference of potential between the terminals A and B were 115 volts, then the difference of potential between A and 4 would be less than 115, while the difference of potential between A and 3 would be less than between A and 4. To start the motor the switch is thrown to the lower position, when the motor will receive the reduced current due to the reduced voltage between A and 4. When the motor is up to speed the switch is thrown to the up position, when the motor will receive the full voltage of the line. If more current is required in starting than can be obtained with the connection at 1 (this being the point of lowest voltage), connection can be made at either 2, 3 or 4 until the current required to start the motor is obtained. Were the motor, while at rest, thrown directly onto the mains without the use of the compensator, the current would rise to six or seven times that normally required, while in starting with the compensator the current varies from full load to about twice full load current according to whether connection is made at 1 or 4.

Fig. 257 shows the connections of the Fort Wayne alternating current, single-phase motor. In order to start this motor and bring it up to speed, the armature is provided with an extra winding connected to the commutator C, shown at the left. When the motor is to be started, the switch S, which is hinged at N, N′, is closed to the left. Current from the left-hand main will then pass through the contacts N′, M′, on the switch S to the series winding, and then to the commutator and armature and out through M, N, on switch, to other side of line. At each reversal of the current the magnetism in both fields and armature is reversed at the same time, thus causing a steady pull in one direction on the armature. As the motor comes to speed the pilot lamp P will gradually light up, and when it has reached full candle-power the switch S is thrown to the right. Current from the left-hand main will now pass through contacts N′, T′, on switch, to the collector rings, through the armature, and out through points T, N, on switch to other side of line. At the same time the contacts V, V′ and W, W′ on switch S will be short-circuited (these points of the switch are not in electrical connection with the blades, being separated therefrom by an insulator, as shown in figure in upper right-hand corner), and the shunt field circuit closed through the commutator; the direct current from the commutator passing from the lower brush through the points V, V′, on switch, to the shunt field and back to points W, W′, and through the rheostat R to the upper brush on commutator. The motor will now run as a synchronous motor, the armature receiving cur-

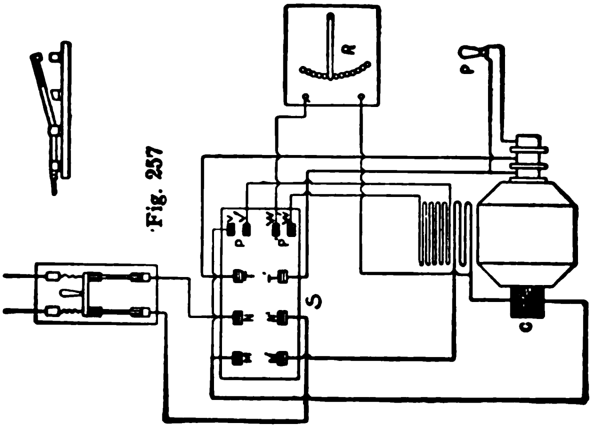


Fig. 257

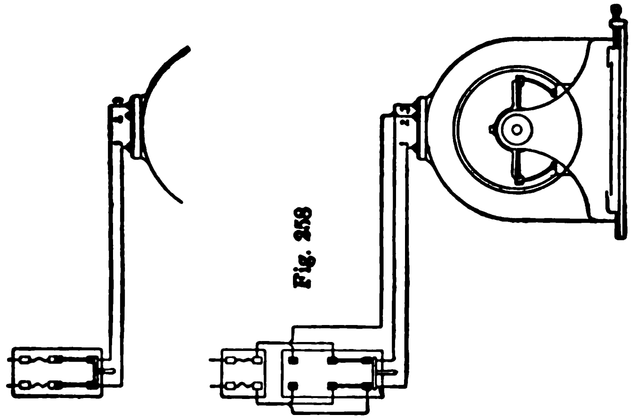


Fig. 258

rent from the mains, while the field is energized by means of the direct current generated in the extra winding in connection with commutator C. When the motor is running with the switch to the right the series field is open.

Fig. 258 shows the connections for the Wagner single-phase alternating current motor. On top of the motor are three binding posts. Posts 1 and 3 are connected to the terminals of the field winding, while post 2 is connected to an intermediate point between 1 and 3. When the motor is called upon to start a heavy load, the double-throw switch shown in the lower diagram is used. With the switch thrown to the upper position connection is made to posts 1 and 2, when, on account of part of the field winding being cut out, a greater amount of current is sent through the fields and the torque increased. When the motor is up to speed the switch is thrown to the lower position, where current will be sent through the entire field winding. The armature winding consists of a number of copper bars terminating in a commutator at one end. While running up to speed the armature is short-circuited through brushes which bear on the commutator and produce in the armature poles which, acting with the fields, cause the armature to revolve. On attaining full speed an automatic governor mounted on the shaft lifts the brushes off the commutator, and at the same time short-circuits all the commutator bars. The motor now runs as an induction motor. The upper connections are used where an ordinary load is to be started.

Alternating current motors vary in design and construction according to the current they are to be used with, whether single-phase, 2-phase or 3-phase. If, in a bi-polar or two-pole dynamo, an armature having one coil properly connected to collector rings were revolved, a current would be generated which would rapidly change both in direction and strength. At each revolution of the armature the current would first rise in strength until it reached a maximum, then die away to zero and again increase and decrease, but in the opposite direction (Fig. 259). Such a current is known as the single-phase current. The common magneto is an example. If two coils were now placed on the armature at right angles, or 90° apart, and properly connected to collector rings and the armature revolved, a 2-phase current would be generated (Fig. 260). Placing three coils on the armature 120° apart would produce three-phase current (Fig. 261).

In the machine described above each complete set or operations is called a cycle or period (A to B, Fig. 259), and the number of periods accomplished in a second is called the periodicity or frequency. If the armature made 60 revolutions per second the current would be generated at 60 cycles. In every revolution or cycle the current flows first in one direction and then in the other, or alternates twice; therefore during 60 cycles there are 120 alternations per second, or 7,200 alternations per minute. Machines are generally rated at a certain number of cycles per second, or so many alterations per minute, viz., 60 cycles, 7,200 alternations, etc.

There are two general classes of alternating current motors, known respectively as synchronous and induction motors. As an example of the first class: If two identical alternating current dynamos are connected together by wires, one running as a generator and the other as a motor, the driven machine would run at the same speed as the driving machine, for, at every change in the direction and strength of the current given out by the generator, like changes would be produced in the machine running as a motor. They would then run in synchronism. It may be advisable to state here that the machine

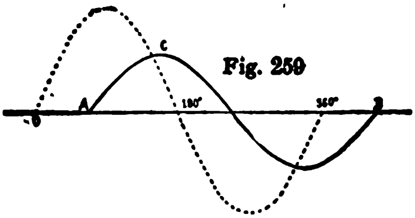


Fig. 259

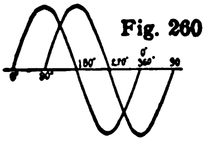


Fig. 260

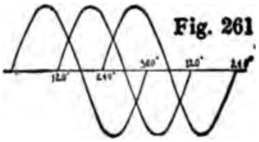


Fig. 261

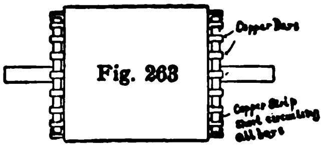
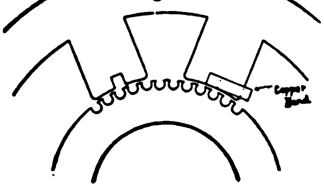


Fig. 263

Fig. 262



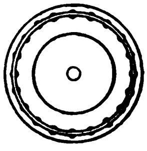


Fig. 264

running as a motor would first have to be brought up to speed, as the majority of synchronous motors are not self-starting.

When a multiphase (2 or 3-phase) alternating current is sent around the fields of an alternating current motor, a revolving field is set up in the space occupied by the armature. If now an armature of what is known as the squirrel cage type (a laminated armature in which bars of copper, running parallel to the shaft, are imbedded in slots in the periphery, the ends of all the bars being connected together, Figs. 263 and 264, is placed in this field, currents will be induced in it which, acting in conjunction with the revolving field, will cause the armature to turn. These are known as induction motors, and this class is generally employed in commercial work. Such motors will start themselves from rest with a considerable torque, and will stand a reasonable amount of overload.

Single-phase motors, unlike the multiphase motors, will not start themselves from rest without the provision of some special means. A number of different methods are in use to make these motors self-starting. In the small fan motors made by the General Electric Co. the ends of the pole pieces are slotted, and around one of the projecting ends is placed a band of copper (Fig. 262). The effect of this band of copper is to cause two magnetic fields under each pole piece, one being slightly out of step with the other. This has an effect on the armature similar to a two-phase current, and causes it to revolve. Another method, known as the split phase, is used for the same purpose. In some of the smaller motors made by the Holtzer-Cabot Co. the field is wound with two separate coils, one having a few turns of comparatively large wire and the other a great number of turns of fine wire. When current is turned on, owing to the difference in self-induc-

tion of the two coils, a field similar to the tw
is set up and the armature caused to revolv
motor has reached synchronism, the curren
resistance coil is opened and the motor op
low resistance coil alone. Other methods
single-phase motors up to speed are describe
and 258. Any small direct-current series
used on alternating current providing the
are laminated. The larger motors generall
much self-induction to be operated on altern

Alternating currents do not always keep
the alternating volts impressed upon the circ
is inductance in the circuit the current will
is capacity (condenser, for instance), the
lead in phase. Fig. 259 illustrates the lag
inductance. The curve V represents th
volts; that marked C is the current curv
measured from O along the horizontal li
time. The impulses of current, represented
line, occur a little later than those of the
the current is increasing in strength the rea
inductance tends to prevent its rising. T
current of 40 amperes in a resistance of 1½
require for continuous current an E. M. F.
but an alternating voltage of 60 volts will n
if there is inductance in the circuit reactin
voltage.

When an alternating current is flowing i
which there is inductance, as the E. M. F. ri
E. M. F. is produced which opposes the imp
F. In other words, induction in a circuit a
a resistance in retarding the current. If, to
power supplied to a motor or other part of a
current circuit, we measure separately with

and volt-meter the amperes and volts and multiply together the readings, we obtain as the apparent watts a value greatly in excess of the true watts, owing to the difference in phase of which the instruments take no account. The true watts can be measured with a suitable watt-meter. Whenever the phase difference is very large, the current, being out of step with the volts, is almost wattless. This is the case with current flowing through a choke coil or condenser if the resistances are small. The ratio between the true watts and the apparent watts is known as the power factor; or, Power Factor = True Watts ÷ Apparent Watts.

Generators.—A diagram of the circuits in the Western Electric Co.'s series arc dynamo is shown in Fig. 265. Constant current series dynamos, like the constant current series motors, are not self-regulating, so that some mechanical means must be employed to keep the current constant. This is accomplished by shifting the location of the brushes, or varying the number of exciting turns on the fields, or in some cases by both these methods combined. In the machine shown the voltage is regulated by shifting the brushes. In the diagram, current flows from the lower or positive brush to the center connection of switch S, and then around the fields and out to the positive side of the line, returning through the regulator R to the upper brush. The switch S is used in starting and shutting down; in the position shown switch is set for running. When it is desired to shut down, the switch S is closed. This first short-circuits the fields and then the armature. The switches shown at the left are used to cut down the current by short-circuiting part of the field windings. They are used where it is desired to operate either the 1200 c. p. arc lamp taking 6.8 amperes, or the enclosed arc lamp taking 6 amperes. With the switches

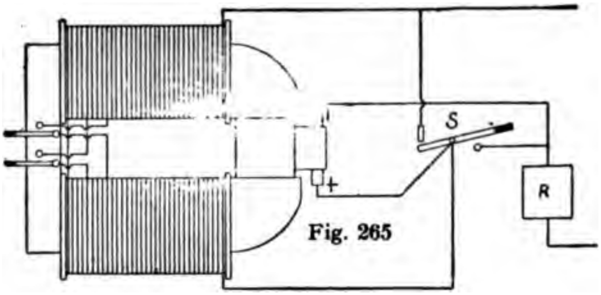


Fig. 265

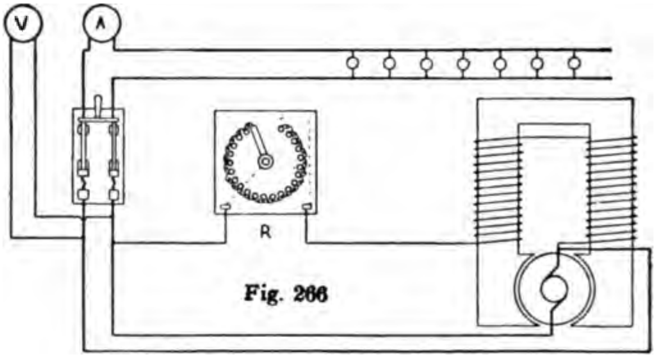


Fig. 266

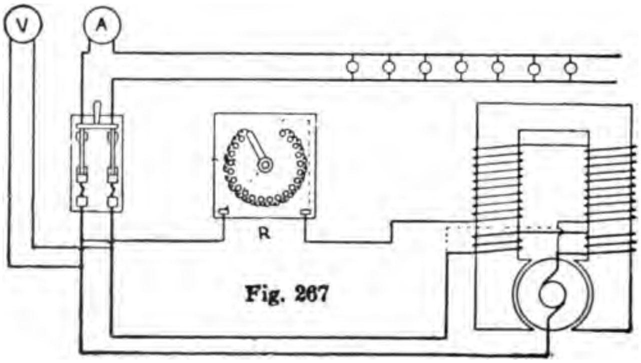


Fig. 267

in the position shown the machine will generate 9.6 amperes, the current generally used on the 2000 c. p. arcs. To reverse the direction of current the armature leads are reversed. In connecting two arc machines in series the + of one machine is connected to the — of the other. The positive side of the machine must always be connected to the positive side of the line.

Fig. 266 shows the connections on a shunt-wound dynamo. The winding varies from that of the series dynamo in having the field magnets, which are wound with a great length of fine wire, connected in shunt across the dynamo brushes. The current in this field is then in shunt with the main circuit, and is generally about 2 or 3 per cent. of the whole current generated by the machine. Shunt-wound dynamos are used where a current of constant potential is desired, such as the lighting of incandescent lamps in parallel, furnishing power for motors, and in storage battery charging and electro-plating. Although the voltage of a shunt dynamo is practically constant, still, as the load is increased, the voltage will gradually fall, and this must be regulated by means of the rheostat R which is connected in series with the field. If resistance is cut out of the rheostat the current in the fields is increased, and the voltage of the machine rises, and vice versa. This dynamo is always protected from overload by a fuse or circuit breaker placed in the main circuit. To start the dynamo it is first brought up to speed and the voltage regulated by means of the rheostat R and the voltmeter V, and the main switch is then thrown in. The connection for the field is taken off the dynamo leads so that the opening of the main switch will not open the field circuit, and for this reason the field will begin to build up as soon as the machine is started. Pilot lamps are sometimes used in place of voltmeter V, the voltage being determined by the brightness of the lamp. This is a very unsatisfactory method and is very little used at the present time. If either the armature or field connections are reversed the current will flow in the opposite direction.

Fig. 267 shows the connections of a compound wound dynamo. This machine, like the shunt wound machine, is used where a current of constant potential is desired, but it has the advantage over the shunt machine in that it maintains the voltage more constant over a greater variation in load. The winding varies from that of the shunt dynamo in having, in addition to the shunt field, an auxiliary field which is in series with the armature. It is in reality the winding of both the shunt and the series machine on one machine. As the current supplied by the dynamo increases, the current in the series field winding increases, thus increasing the field magnetism and the voltage. In this way the voltage is kept practically constant. When a dynamo of this kind is used to supply a large load located at some distance from the generator, it is sometimes desirable to have the voltage at the dynamo terminals increase as the load increases, to overcome the increased drop in the line due to the losses from increased current. To accomplish this a method known as over-compounding is used, the series windings being so calculated that, as the current increases, the voltage will rise accordingly. In some cases the shunt field is connected between one brush and the end of the series winding, as shown in the dotted lines. This is known as the long shunt, the method of connecting directly across the brushes being known as the short shunt. A rheostat R is connected in the shunt field and serves the same purpose as in the shunt machine.

Fig. 268 shows the connections when two shunt-wound machines are to be run in parallel. The winding of these machines is the same as shown in Fig. 266. The positive lead of each machine is connected to the same bus bar. In starting, if it is desired to use but one machine, the method described in Fig. 266 is followed. When one of the machines is running and the other is to be thrown in, the idle machine is brought up to speed with the main switch open and the voltage regulated by means of the rheostat and voltmeter until the voltages of the two machines correspond. The main switch is then thrown in and the load on the two machines, which is ascertained by the ammeters, is equalized by means of the rheostats. If there is any great difference in voltage between the machines, the higher one will run the other as a motor without changing the direction of rotation. The field current will remain unchanged and the armature current of the low dynamo will be reversed, which will cause it to run in the same direction as a motor as it ran as a dynamo. When a plant feeding motors is shut down the switches on motors should first be opened, or very likely motor fuses will blow. As the voltage goes down the motors will draw more current to do the work. If a plant is shut down with the motor switches "on" it will generally be found impossible to start up a shunt dynamo, the low resistance in the mains not allowing enough current to flow around the shunt fields to energize them.

Fig. 269 shows connections for two compound wound dynamos run in parallel, the winding of each machine being the same as in Fig. 267. When two or more compound wound dynamos are to be run together, the series fields of all the machines are connected together in parallel by means of wire leads or bus bars, which connect together the brushes from which the series fields are taken. This is known as the equalizer, and is shown by the line

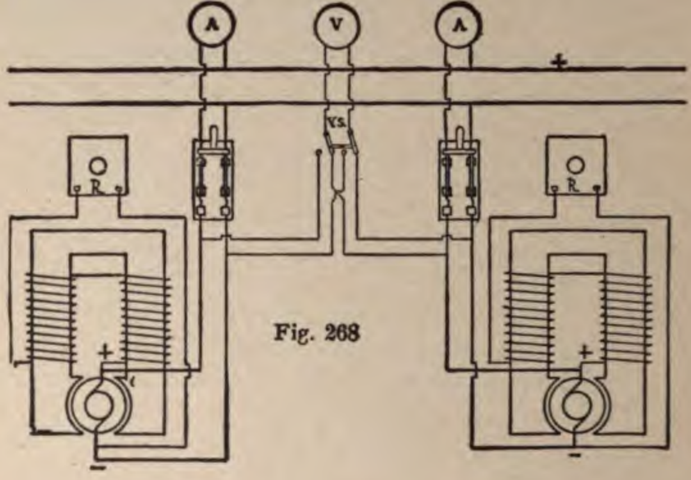


Fig. 268

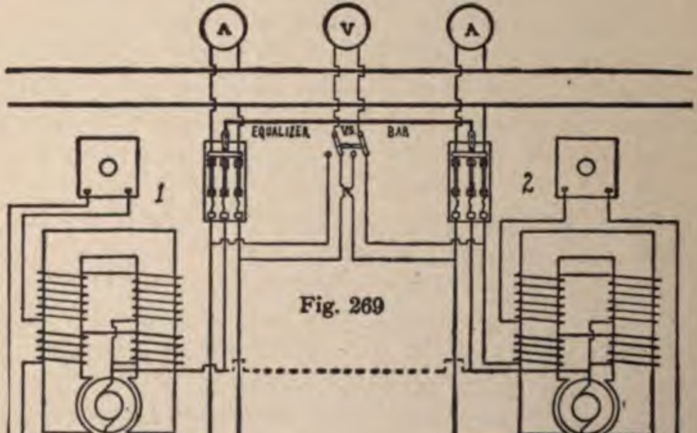


Fig. 269

running to the middle pole of the dynamo switch. By tracing out the series circuits it will be seen that the current from the upper brush of either dynamo has two paths to its bus bar. One of these leads through its own fields, and the other, by means of the equalizer bar, through the fields of the other dynamo. So long as both machines are generating equally there is no difference of potential between the brushes of Nos. 1 and 2. Should, from any cause, the voltage of one machine be lowered, current from the other machine would begin to flow through its fields and thereby raise the voltage, at the same time reducing its own until both are again equal. The equalizer may never be called upon to carry much current, but to have the machines regulate closely it should be of very low resistance. It may also be run as shown by the dotted lines, but this will leave all the machines alive when any one is generating. The ammeters should be connected as shown. If they were on the other side they would come under the influence of the equalizing current and would indicate wrong, either too high or too low. The equalizer should be closed at the same time, or preferably a little before, the mains are closed. In some cases the middle, or equalizer, blade of the dynamo switch is made longer than the outsides to accomplish this. The series fields are often regulated by a shunt of variable resistance. To insure the best results compound machines should be run at just the proper speed, otherwise the proportions between the shunt and series coils are disturbed.

Fig. 270 shows connections where two shunt-wound machines are connected to operate on what is known as the three-wire system. The two dynamos are connected in series, three wires being carried from them; one from the outside pole of each machine and one from the junction of the two machines. The voltage

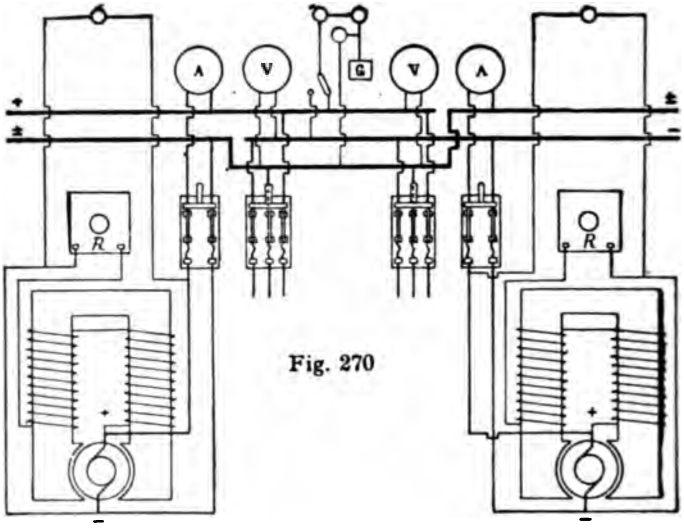


Fig. 270

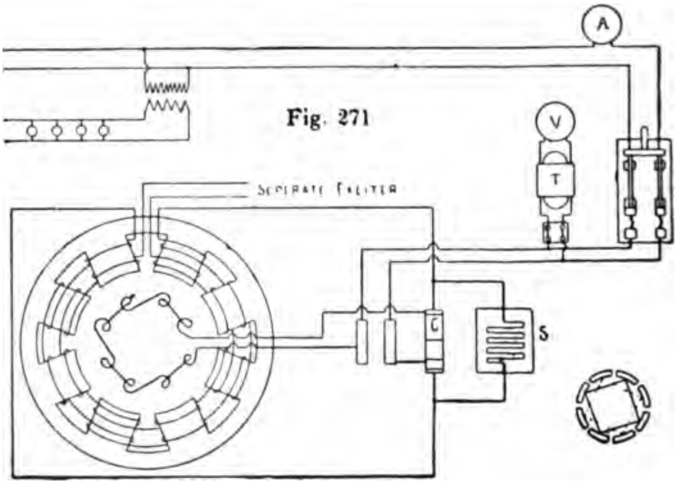


Fig. 271

between these outside wires is equal to the combined voltage of the two machines, and the voltage between the outside and the central or neutral wire is equal to the voltage of the corresponding machine. If the load on both sides of the system is equal there will be no current flowing in the neutral wire, while if the loads are unequal the neutral wire will have to carry only the difference in currents between the two outsides. The advantage derived from the use of the three-wire system lies in the fact that one wire (which would have to be used were the two machines operated on two separate circuits) can be done away with, and on account of the voltage being doubled the wires can be of much smaller capacity. For the same per cent of loss the amount of wire required to operate the three-wire system, where the neutral wire is of the same size as the outsides, is but three-eighths of that required with a two-wire system. This system is used to a great extent in the large cities for central station direct current distribution, and it is also used on the secondary mains in alternating current work. In the feeder lines of the direct current system the neutral wire is generally made one-third the size of the outsides, while in the secondary mains in both direct and alternating current work all three wires are made of the same size, for the reason that if one of the outside fuses should blow the neutral will have to carry the full current.

Single-Phase Alternator. Fig. 271 shows the connections of a single phase alternating current generator. The field of this machine is excited by a direct current, part of which is taken from some outside source (generally a small dynamo belted to the shaft of the alternator) and part of which is taken from the windings of the alternator, the current being rectified by means of the commutator C. This commutator has as many segments as there are poles to the dynamo, and the alternate segments are connected together as shown in the small diagram. S is a German silver resistance which is connected in shunt across this rectifying commutator. The main current coming from the armature is shunted, part going through the shunts, the remainder around the field winding. It will be seen that this method of field excitation is very similar to that used on the compound wound direct current dynamo. In the diagram shown both of the field windings encircle every pole, but in some machines the rectified current will traverse a few poles only, the current from separate exciter traversing the remainder. Current on these machines is usually generated at high voltage, and transformers are used at the point of supply to cut the voltage down to that required. The transformer T is used in connection with voltmeter V to reduce the voltage on that instrument.

Compensator. Fig. 272 shows the wiring diagram of a compound wound compensator set. These machines are used in connection with a 220-volt generator, and make it possible to obtain 110 volts for lamps or small motors when desired. This set consists of two motors, the armatures of which are mounted on one shaft so that both must run at the same speed. The switch P and the circuit breaker must be open when the machines are started. The main switch being closed the current enters at the positive pole and passes through the starting box to the armature and series field of B, and thence through the armature and series field of A back to the negative side of the line. Similarly the shunt fields are also in series. The machines are started like ordinary motors, and when they have attained full speed switch P is closed and the rheostat R is adjusted until the voltage on the two ma-

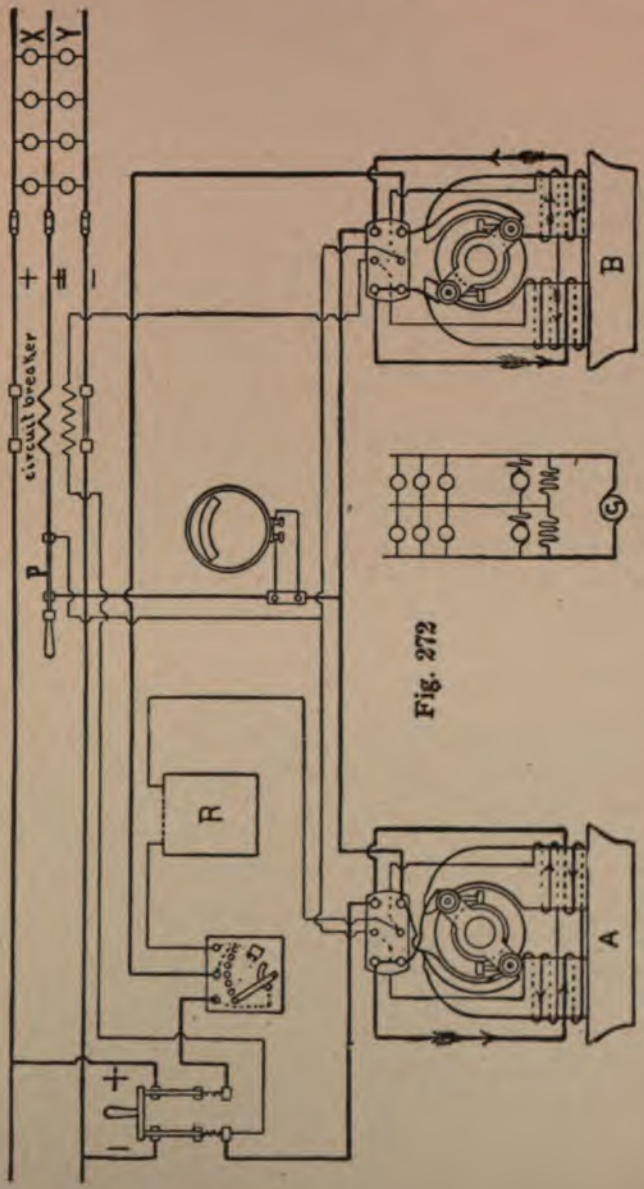


Fig. 272

chines is equal. The voltmeter is not shown in the drawing, but is connected as in Fig. 268, so that a reading from etiher machine may be taken. The voltmeter used should be capable of measuring the total voltage of the supplying generator. When the machines are at even voltage the circuit breaker is thrown in. It will be noticed by the direction of the arrows that the currents in the series fields and shunt fields are in opposition. This remains so in both motors only while the load on both sides of the neutral is even, and under this condition the current in the series fields is very small. If, now, an additional load is thrown on, say ten lamps at X, this current cannot pass through Y, and therefore passes along the neutral wire to the armature and series field of A. This current being in opposition to that in the shunt fields weakens them, and thereby causes the motor to speed up. This speeding up increases the counter E. M. F. at B, the fields of which have not been weakened, and it becomes a generator. It cannot, as a generator, give out more power than it receives from A, and will generate a little less than one-half of the excess current used at X. The rheostat must be located in the strongest field. Where automatic starting boxes are used, as in this case, it is nearly always necessary to place the rheostat in the opposite field to balance the resistance of the magnet on starting box. The elementary diagram is introduced to show circuits in a simpler manner.

Switchboards. Fig. 273 shows the wiring and connections of the Western Electric Co.'s series arc switchboard. At the top of the board are mounted six ammeters, one being connected in the circuit of each machine. On the lower part of the board are a number of holes, under which, on the back of the board, are mounted spring jacks

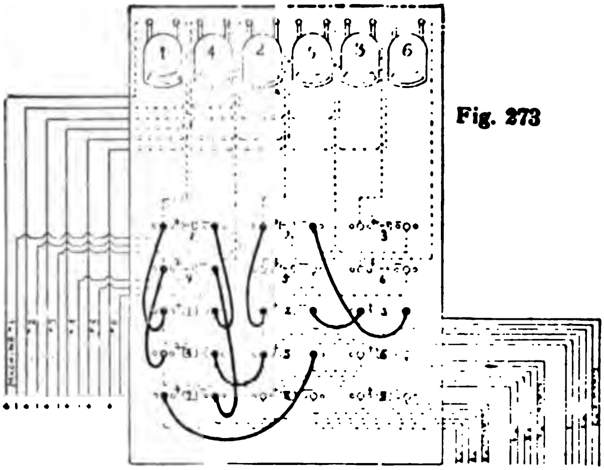


Fig. 273

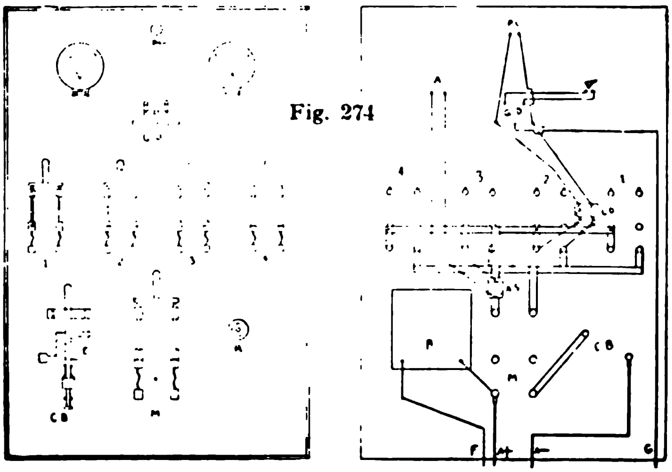


Fig. 274

to which the circuit and machine terminals are connected. For making connections between dynamos and circuits, flexible cables terminating at each end in a plug, are used, these are commonly called jumpers. The board shown has a capacity of six machines and nine circuits, and with the connections as shown machine 1 is furnishing current to circuit 1, machine 2 is furnishing current to circuits 2 and 3, and machine 4 is furnishing current to circuits 4, 5 and 7. In connecting together arc dynamos and circuits the positive of the machine (or that terminal from which the current is flowing) is connected to the positive of the circuit (the terminal into which the current is flowing). Likewise the negative of the machine is connected to the negative of the circuit. Where more than one circuit is to be operated from one dynamo, the — of the first circuit is connected to the + of the second. At each side of the name plate (at 3, for instance) there are three holes. The large hole is used for the permanent connection, while the smaller holes are used for transferring circuits, without shutting down the dynamo. Smaller cables and plugs are used for transferring. If it is desired to cut off circuit 5 from machine 4, a plug is inserted in one of the small holes at the right of 4, the other plug being inserted in one of the holes at the left of 7. Circuit 5 would now be short circuited, and the plug in the + of 5 can now be transferred to the permanent connection in the + of 7, and the cords running to 5 removed. If it is desired to cut in a circuit, say circuit 6 onto machine 2, insert a cord between the — of circuit 2 and the + of 6 and another between the — of 6 and the + of 3. Now pull the plug on the cord connecting—of 2 and the + of 3 and insert the permanent connections. In cutting in circuits, if they contain a great number of lights, a long arc may be drawn when the plug between 2 and 3 is pulled, and it is sometimes advisable to shut down the machine when making a change of this kind.

In Fig. 274 the switchboard connections and all necessary instruments for operating a single (shunt or compound) dynamo are shown. Such a board could be used on a small isolated plant. At the left a front view with the instruments is shown, while at the right is a rear view showing the connections. Referring to the view at the left, X is a voltmeter and A an ammeter with scales suitable to the voltage and current used. PL is a pilot lamp. The ground detector switch GD is used to measure the insulation resistance to ground of each side of the system. In the position shown the voltmeter is connected directly across the bus bars. If the switch is moved to the right, the + bus bar is connected through the voltmeter to ground, and, by means of the reading obtained, using the formula given under the head of testing, the insulation resistance can be determined. Moved to the left, the insulation resistance of the other side of the system can be obtained. One of the dynamo leads is carried to one terminal of the main switch M, while the other lead is carried through the circuit breaker CB to the other terminal of the switch. The circuit breaker is generally set to operate at a lower rise in current than the fuses on switch M, so that these fuses only blow in case the circuit breaker fails to operate. The circuit breaker is not absolutely necessary, but is generally installed in well designed plants. The small hand wheel R is connected to the rheostat mounted on the rear of the board. The switches 1, 2, 3 and 4 operate the feeder lines. On the rear of the board the three wires F, A + and A —, go to the dynamo, while the line marked G is connected to some good ground, such as a water pipe. The rheostat R is connected in series with the shunt field, and is used to regulate the voltage. AS is a shunt connected in series with one of the bus bars, the terminals of the shunt being connected to the ammeter. This shunt is generally furnished with the ammeter. In case an ammeter which carries the entire current is used, leads must be carried to the ammeter so that it will be connected in series with one of the mains. The feeder lines are connected to the upper terminals of switches 1, 2, 3 and 4. The ground detector, pilot lamps and voltmeter are connected to the bus bars through the cut-out CO, standard No. 14 rubber covered wire being used on these circuits.

Ground Detectors. In Fig. 275 a ground detector switch suitable for mounting on a switchboard is shown. Two arms A, A′, pivoted at their upper ends, are connected together with an insulating bar B. These arms make contact at their lower ends with two brass strips and a contact button which are connected to the bus bars and ground respectively. When the arms are moved to the left the + bus bar is connected to ground through the voltmeter V. By means of the reading obtained the insulation resistance to ground of the — side of the line can be calculated by using the formula given further on. By moving the arm to the right the insulation resistance of the + side of the line can be obtained.

Fig. 276 shows a lamp ground detector. On a 110-volt sytem two ordinary 110-volt lamps are connected in series, while the line connecting the lamps is connected to ground through a snap switch S. When current is on, the two lamps will burn with equal brilliancy at a low candle-power. When the switch S is closed, if the two lines are clear the brilliancy of the lamps will not be affected; but if there is a ground on the + side of the line lamp 2 will burn brighter, the brightness depending on the resistance of the ground. If there is a dead ground

Fig. 275

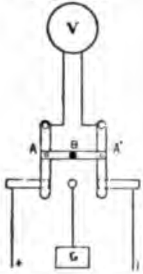


Fig. 276

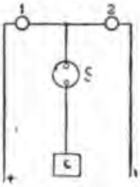


Fig. 277

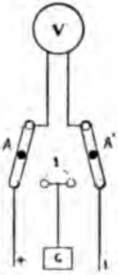


Fig. 278

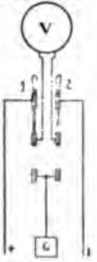


Fig. 279

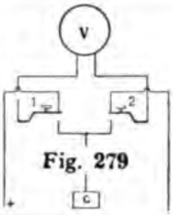


Fig. 280

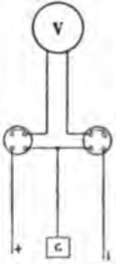


Fig. 281

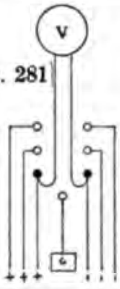


Fig. 282

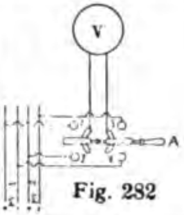


Fig. 283

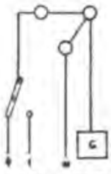
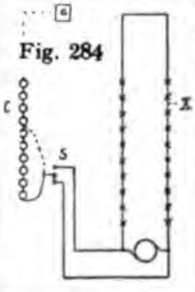


Fig. 284



the lamp will burn at full candle-power, lamp 1 not burning at all. If the ground is on the — side of the line lamp 1 will burn brighter.

Fig. 277 shows another method of using a voltmeter as a ground detector. The arms A A′ are hinged at the upper ends and swing separately. Arm A moved to post 1 gives the reading on the + side, and arm A′ moved to post 1 gives the reading on the — side of the line.

Fig. 278 shows another method, using two single-pole double-throw knife switches. Throwing switch 1 to lower position connects the — bus bar to ground, and gives the insulation resistance of the + side of the line.

Another form in which two double-point push buttons are used is shown in Fig. 279. In normal position contact is made to the upper points so that the voltmeter is always connected across the bus bars. Pushing button 1, the insulation resistance of the + side of the line can be obtained, and pushing button to the — side.

Three-way snap switches are used for the same purpose in Fig. 280.

When several machines are in operation the method shown in Fig. 281 can be used. With this arrangement the voltage can be taken on any one of several lines or machines, and also the insulation resistance to ground. The voltmeter connection is made by means of flexible cords terminating in plugs, which fit in the jacks, which in turn are connected to the machine leads or to the various circuits.

The switch shown in Fig. 282 is designed for use where two dynamos are run in parallel. An arm A pivoted at the center is equipped with brass strips, which, by moving arm A, make contact between the center curved piece and the contact points 1, 2, 3 and 4. With the arm moved down the voltmeter is connected to machine No.

1, and with the arm moved up the voltmeter is connected to machine No. 2. By a slight movement of the arm the voltage of either machine can be taken. This is useful where a dynamo is being brought up to speed to connect on to the bus bars.

Fig. 283 shows a lamp ground detector for use on a three-wire system where the neutral is not grounded. In nearly all three-wire systems the neutral is either permanently grounded or becomes grounded so that ground detectors are not used, a ground on either of the outsides blowing a fuse.

Fig. 284 shows a method of locating grounds on a series arc line, where lamps are burning. A number of incandescent lamps are connected in series, the last lamp being connected to ground. Two wires are carried to the double-throw switch S, one wire being connected to each side of the circuit. From the middle of the double-throw switch a flexible connection is carried to the first lamp, and the brightness of the lamps noted. If the lamps do not burn up to full candle power, connection is made at some lamp nearer the ground, and this continued until the lamps burn at full brightness. When this point has been reached the number of lamps is counted, and if 100-volt incandescent lamps are used it will be seen that there are just twice as many arc lamps burning between that side of the machine and the ground as there are incandescents burning, for an arc lamp takes approximately 50 volts. In the diagram suppose there is a ground on the arc circuit at X, then, with the connection to the incandescent lamps as shown in the dotted lines, the lamps will burn at full brightness. Care should be taken in handling an apparatus of this kind on account of the high voltages on arc circuits on which there are a number of lamps.

Storage Batteries. Fig. 285 shows a diagram of connections of a storage battery and booster suitable for an ordinary electric light installation, where it is desired to

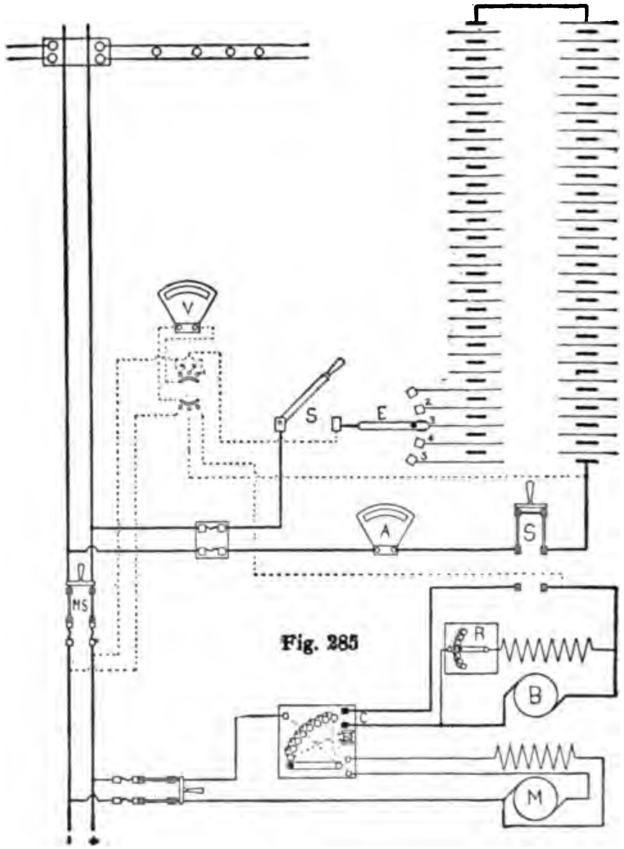


Fig. 285

use the battery at time of heavy load to assist the generator, and to use the battery alone at time of light load. The booster B, which is driven by the motor M, the two forming a motor generator set, is connected in series with the battery circuit, and serves to raise the voltage to that necessary to charge the batteries. R is rheostat in the field of the booster by which the E. M. F. can be regulated. To charge, the double-throw switch S is thrown downward and S is closed, the end-cell switch E being placed on point 5 so that all the cells are in circuit. The motor is now started, and when it is up to speed the arm of the motor rheostat closes the charging circuit at C. To discharge, throw the end-cell switch E to point 1 and throw double-throw switch S upward. The battery is then in parallel with the generator. To run with the batteries alone open switch MS.

As the E. M. F. of the battery falls, more end-cells are switched in by moving switch E to points 2, 3, 4 or 5. A separate voltmeter is generally installed so that the readings of the voltage may be taken from the end-cells separately, to prevent overcharging or exhausting them. In power work, where variations in voltage are greater and not of so much importance, storage batteries are often connected directly across the mains without a booster. In such cases the battery will take current from the mains when the load is light and the voltage correspondingly high, and give current into the line when the voltage becomes low due to heavy loads.

Testing. Fig. 286 is designed to illustrate a method of testing out rough wiring when lights or fixtures are to be connected. All wiring may be considered concealed except the ends at outlets, and it is assumed that nothing is known of how the wiring is run in. The first step is to separate all wires at outlets, so there may be no wrong connections. Next connect an ordinary bell and battery as shown in the figure and fuse up the circuit. If the bell now rings, there must be a short-circuit in the wiring lead-

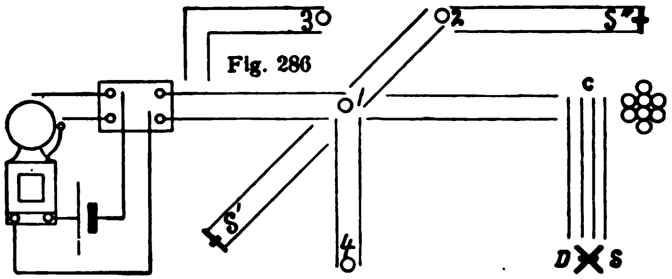


Fig. 286

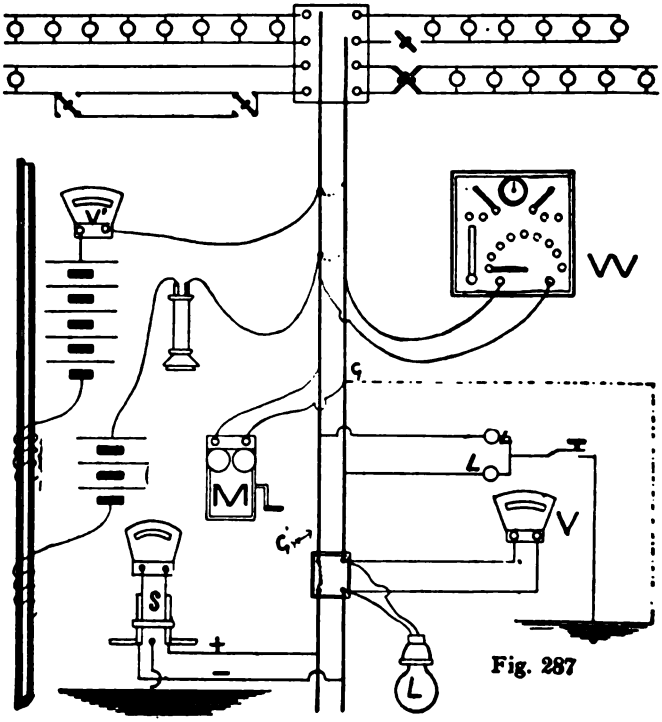


Fig. 287

ing direct from the cut-out, since we have disconnected all other wires. To locate this it will be necessary to get access to the wiring, and it may be necessary to tear off plaster or break into walls. Oftentimes it is better to abandon a circuit with such trouble as this and run in a new one. If the circuit is found clear, the next step is to temporarily bring together the bare ends of all the wires found at any of the outlets until a ring from the bell is obtained. When a ring is obtained it will indicate that the circuit feeds direct to this outlet from the cutout. Next pick out at this outlet the two wires which together produce a ring. These two wires come direct from the cutout, and may now be marked as such. In the figure it is intended that the light 1 shall be controlled by the switch S′, and the light 2 by the switch S″, the lights 3 and 4 are not provided with switches, but the large chandelier C is to be controlled by the double-pole switch DS. The next step will be to find the two wires leading to switch S′. To accomplish this, close the switch and bring any two of the wires found at outlet 1 in contact with those coming from the cutout; when the proper wires have been thus connected the bell will ring. One of the switch wires may now be connected permanently to one of the circuit wires coming from the cutout, while the other is to be connected to one side of the lamp or fixture. The other wire coming from the cutout goes to the other side of the lamp or fixture. Lamp 1 is now completely connected and under control of switch S′. The quickest way to find the proper connections for lamp 2 and switch S″ is by bunching all the wires at 2, and then trying at 1, any two wires to those coming from the cutout until the bell rings. The two wires which cause this ringing lead direct to lamp 2, and may now be connected to the wires leading from the cutout, care being taken that they are connected so as not to come under control of switch S′. Next, separate the wires at 2, and find those which when brought together cause the bell to ring; one of these must be connected direct to the lamp or fixture, while the other is connected to one of the remaining wires. This leaves one wire, and it connects to the other side of the lamp and completes the connection of lamp 2 and switch S″. The four remaining wires at 1 may be found in a similar manner, care being taken that they are also connected behind the connections of switch S′. Two of the six wires at outlet C may now be connected direct to those coming from outlet 1. After this, go to switch DS and find the wires coming from outlet 1 and the cutout (by ringing the bell), and connect them to the proper points on the switch. The remaining wires connect to the other pole of the switch and to the chandelier. The wires leading to lamp 3 may be doubled up under the screws of the cutout terminals. For testing of this kind the bell shown is the most convenient instrument, since it is audible at quite a distance, and a circuit as described often extends through several rooms. A magneto may also be used, with an assistant to turn the crank, or if the circuit at the cutout is short-circuited the wireman may carry it with him, making connections wherever he wishes to test. If the cutout center is alive a lamp may be placed instead of one of the fuses, and the wireman may carry another with him for testing. A galvanometer or telephone receiver may also be used in this way, the battery alone being connected at the cutout center.

Fig. 287 shows the main and branch wiring of a two-wire incandescent system, all complete and ready for final test and connection. In the first place it is necessary to close all the switches and insert all fuses, and a test for short circuits or faulty insulation between opposite poles may then be made by placing a lamp L in circuit in place of one of the main fuses. If current is now thrown on the lamp will light, in case there is any serious defect in the insulation between opposite polarities in any part of the system. In case there are any two or three-way swtiches controlling lights from several places, it will be necessary to turn one of these on each circuit after the first test has been made and then make another test—since one cannot well be certain whether such switches close a circuit or not unless a lamp can be seen to burn. It will also be advisable to do this with single and double pole switches, and may often be easier than removing covers from snap switches to see whether they are on or off. Snap switches will often indicate by the sound of the snap whether they are on or off, but this is not always reliable. If a more thorough test than that given by the lamp is required, it may be made with any one of the four instruments shown. The voltmeter may be connected in place of the lamp. If the system is perfect the voltmeter will indicate nothing, while if a short-circuit exists it will indicate the full pressure. A telephone receiver may also be used in the same way, if properly wound, and if the system contains no lead-covered wires or iron pipe and is not too large. If the Wheatstone bridge W, or magneto M is to be used for this test, both main fuses must be removed and connection made to both wires as shown with these instruments. Lead-covered wire, or wire in iron pipe, will also interfere with testing by a magneto, a ring sometimes being obtained when the insulation of the system is perfect. The figure also shows the voltmeter V′ and the telephone receiver fitted up with battery to test the insulation resistance to earth of lines having no current; the same connections may be made with the magneto or Wheatstone bridge, and both main wires may be connected at once as shown by dotted lines. More detailed explanation and formulas for testing with the voltmeter and Wheatstone bridge will be given further on. When it is desired to ascertain the current passing along the mains, an ammeter may be connected in place of voltmeter V as shown. To test the insulation resistance accurately, the system should not be alive, although approximate tests may be made with a voltmeter or ground detector lamps connected as shown in Fig. 287. This method of testing live circuits is practical only on small systems, since the system cannot be subdivided, and the indications are accurate only so long as defects are confined to one side of the line. With large three-wire systems it is quite usual to have the neutral wire grounded, and these methods could not be used at all.

In Fig. 287 there are shown two ground detector lamps L and L′, and by means of a key or switch the wire between them may be connected to ground. As long as this key is not brought in contact with the ground wire, both lamps burn dimly in series and with equal brilliancy, and if no ground exists in any part of the system, depressing the key will not affect the lamps. Should, however, a ground exist, say at G, closing the key will establish a path through the ground and through lamp L′ to the opposite side of the circuit. If the ground is of very low resistance the lamp L′ will burn at full candle power, while L will not burn at all. Should the ground be of high resistance there will be but little difference in the brilliancy of the lamps. The connections of the voltmeter are based on the same principle. The switch S moved one way makes connection with the positive pole through the voltmeter to ground, and moved the other way makes connection with the negative pole through voltmeter to ground. In the position shown the switch is clear of the ground, and connects the voltmeter to the lighting mains so as to obtain full pressure. The formula for use with the voltmeter when the exact value of the resistance is to be determined is $X = R \left\{ \frac{E - E'}{E'} \right\}$ where E is the full voltage of the battery or other source of current as indicated on the voltmeyer, E′ is the reduced reading obtained through the voltmeter and the resistance to be measured, and R the resistance of the voltmeter, X being the value of the unknown resistance. This formula is based on the supposition that the voltmeter and the resistance to be measured are in series, and that all current passing through the voltmeter and the resistance to be measured also passes through the voltmeter. Referring to Fig. 287, so long as G is the only defect on the system allowing current to flow, the above formula will give us the correct resistance; as soon, however, as G′ is introduced the formula becomes unreliable, since G′ is a shunt around the voltmeter and robs it of current. The passing through the voltmeter no longer depends only on the voltmeter resistance and that of G, and therefore the readings can no longer be used as a basis of calculations. As a matter of fact, if the voltmeter test on a live system as shown in the figure indicates a low ground on one side, as, for instance, G′, it will usually show the other side very high. The ground detector lamps are subject to the same limitations, but although they and the voltmeter cannot be relied upon for accurate testing, both are very useful when arranged so that tests can be made several times per day, so as to give means of detecting a ground as soon as it comes on.

SMALL BELT DRIVE MOTORS.

A small belt drive motor is shown in Fig. 288. The shaft is turned from best machine steel. Generous fillets are provided at all changes of section, and such an ample allowance as regards strength, that fracture from long continued vibration or alternatintg stresses becomes impossible.

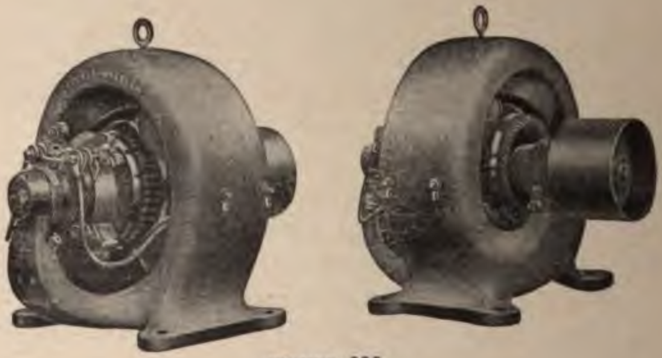


FIGURE 288.

The journal boxes are carefully fitted to rigid supports, and are provided with oil rings, which, dipping into reservoirs in the bearings, insure perfect lubrication. Oil slings and oil retaining lips have been given very careful study, and are so designed that not even at the highest speeds will there be the slightest throwing of oil.

The field coils are wound on forms and thoroughly insulated, the outer surface being protected from mechanical injury by a covering of stout insulation coated with moisture-proof varnish.

Brass terminal connectors are securely fastened to each coil.

The armature winding is of the barrel type, having formed coils laid into open-top slots. Special attention is given to the ventilation of the core and windings in order to insure the machine against running dangerously hot under overloads. The proportions of core and winding have been the subject of careful design, to reduce to a minimum those influences which promote sparking at the brushes.

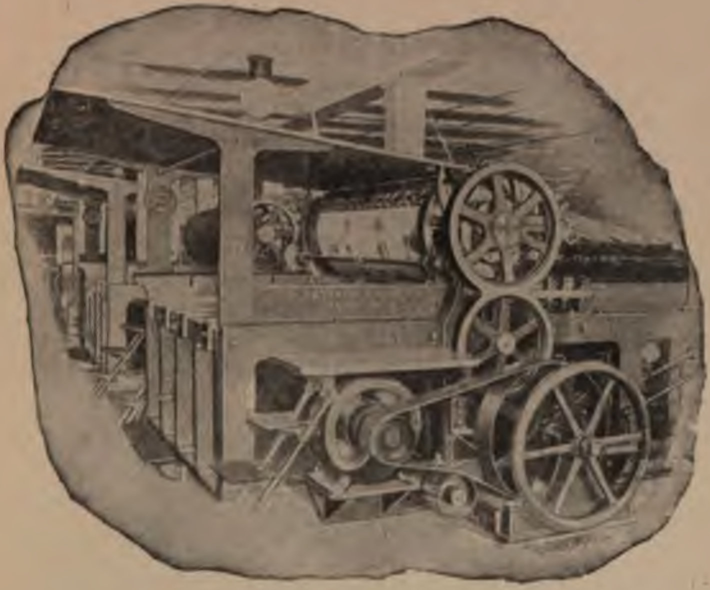


FIGURE 289.

The insulation of the armature is of the highest grade, the materials being chosen with regard to their endurance under heat, moisture and the severe conditions of actual use. The losses and delays due to short circuits and burn-outs are thus minimized.

The commutator is of simple design, well made, and is subjected to a separate insulation break-down test before approval. The bars are of hard drawn copper, and for insulation only the best and most uniform grades of mica are used. The material and methods of construction are such as to produce a well ventilated and yet rigid body, designed to cause equal wear of copper and mica.

The purposes for which a machine of this size can be adapted are numerous and varied. The illustration in Fig. 289 shows an attachment for driving machines by a motor mounted on a frame of the tool or press. When belted, the application is simple, the motor being supplied with a railbase for belt tightening purposes.

SMALL DIRECT DRIVE MOTORS.

Figure 290 illustrates a small direct drive motor.

The commutator is supported on a drawn steel tube with bronze clamping flanges and is built up of hard drawn copper bars. The insulation consists of selected mica of the best quality.

The brush holder and its support are of remarkably simple design and rugged construction and require no special adjustments. The brush holders are supported on studs passing through the end shield and insulated from it by porcelain bushings. The outer ends of these studs are provided with nuts for attaching the line wires.

When the open motors run at full rated load continuously the temperature in any part will not exceed 40 degrees C above that of the surrounding air.

The magnet frame shown in Fig. 291 is of steel and has two internal poles, fitted with removable shoes, by which the field coils are kept in place. The end shields, carrying the bearings and brush rigging, are of cast iron, and are held to the magnet frame by cap screws. The shield which carries the brush rigging has three slots through which the cap screws pass, and the brush position is accurately adjusted by rotating this shield. Proper adjustment is made before the machine leaves the factory, and no further brush adjustment is required.

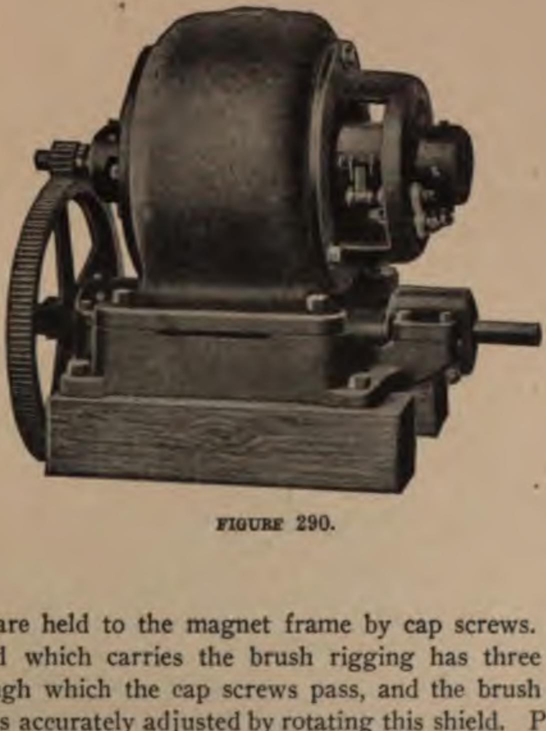


FIGURE 290.

The shield at the back of the motor is held by four cap screws. When it is desired to adjust the motor for wall or ceiling suspension, the cap screws are removed from the back shield and it is rotated 90 or 180 degrees to place the oil well beneath the shaft. The front shield remains unchanged, but by loosening a screw its journal box may be rotated 90 or 180 degrees. The oil well of the front shield is of equal depth on all sides of the shaft and the oil ring may hang in any direction. The con-

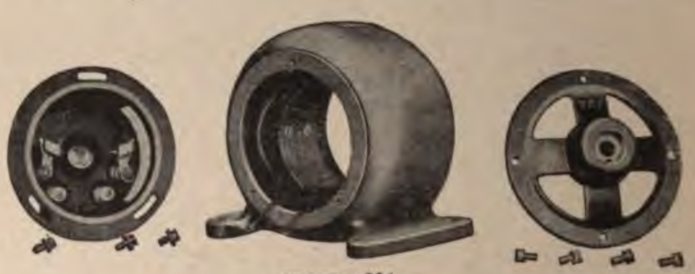


FIGURE 291.

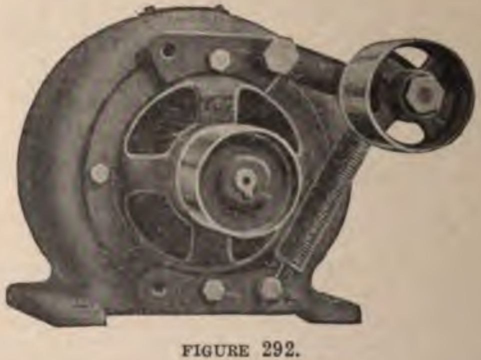
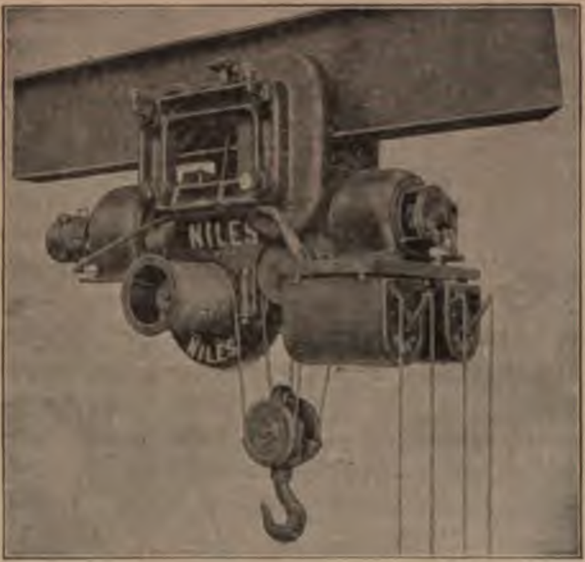


FIGURE 292.

struction of the end shields is plainly shown, the rear one to the right and the front one to the left, of the finished frame. The openings in the end shields can be closed by covers, when complete inclosure is desired.



FIGURF 293.

There are two field coils of rectangular shape. These coils are wound on forms, and heavily insulated and taped, every precaution being taken to make them moisture proof. The coils are held in place by the removable pole shoes.

The armature core is built up of steel laminations insulated from each other and slotted to receive windings. The core is mounted on and keyed to the steel shaft. The armature windings are form-wound coils, taped, baked and varnished. Every precaution is taken to secure high insulation and durability.

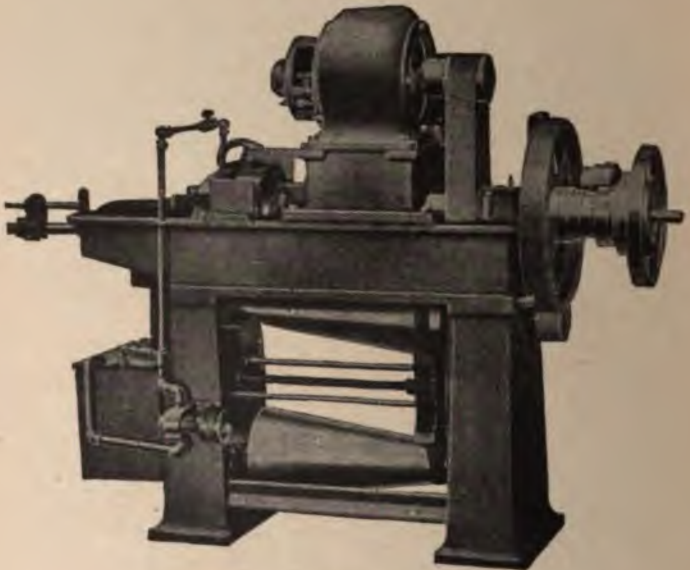


FIGURE 294.

A simple and serviceable belt-tightening idler may be attached to the frame of any standard motor and adjusted at any desired position as shown in Fig. 292. Figures 293, 294 and 295 show some of the applications of these motors to drive different types of machinery.

WESTINGHOUSE POLYPHASE INDUCTION MOTOR.

An induction motor as shown in Figs. 296 and 297 consists of two parts, a stationary primary and a rotating secondary. The rotating element is carried by two bearings supported by end brackets which are bolted to a solid cast-iron frame. The line circuit is connected to the

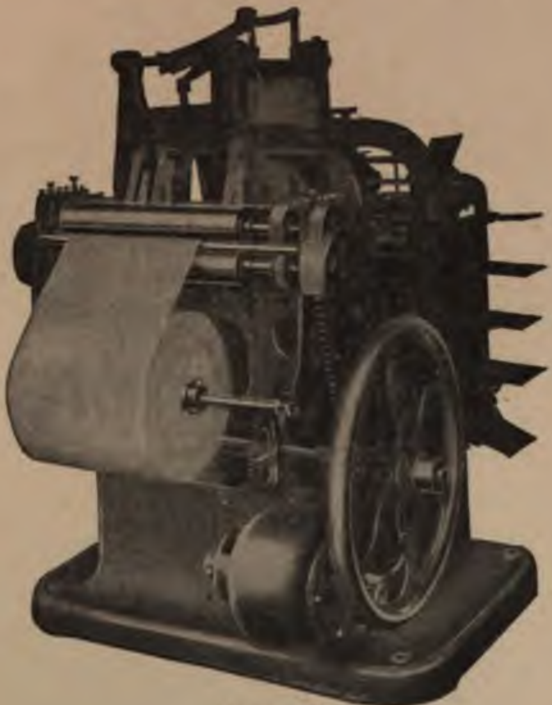


FIGURE 295.

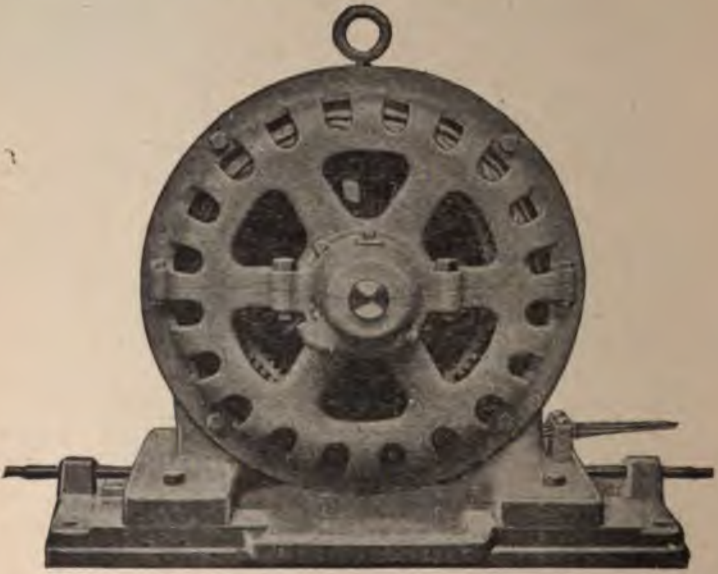


FIGURE 296.

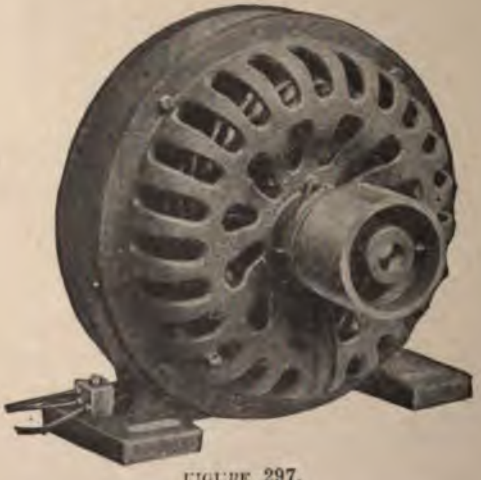


FIGURE 297.

stationary winding, and the rotor being of the squirrel cage type, no sliding contacts are employed. The only wearing parts of the machine are the bearings, and as these are of ample dimensions with a light revolving element and excellent oiling facilities, the wear is exceedingly slight. Such a motor may be placed in any convenient location without regard to its accessibility, as the only requirement for its satisfactory operation is that the oil reservoirs be kept filled, an attention required by the simplest shafting. Not only does it give entire satisfaction in service, but what is even more essential, it will always operate. The importance of this feature of reliability cannot be too strongly emphasized, for a shutdown, even for a short time, often causes great annoyance and expense.

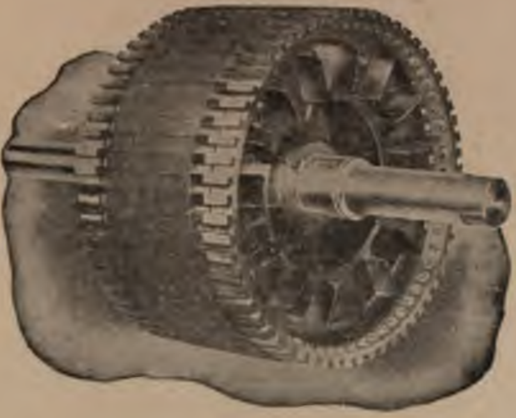


FIGURE 298.

The laminations forming the stator core are mounted in the hollow cylindrical cast-iron frame. The cores of the machines are built up of continuous rings of steel punchings. Leads for connection to the supply circuit are brought out through terminal cleats on the foot of the frame. Hand connectors are supplied on the terminals of every motor.

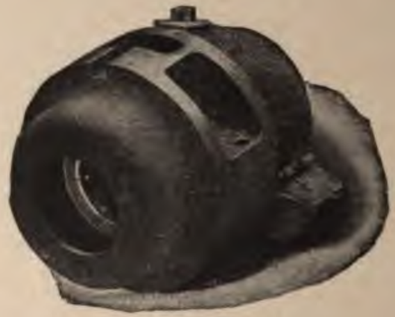


FIGURE 299.

The core of the secondary or rotor shown in Fig. 298 is built up of high grade steel punchings mounted on a cast-iron spider which is keyed to the shaft.

The windings consist of insulated copper bars lying in partially closed slots around the periphery. The conductors are connected together at each end by a copper or brass ring of large cross-section to which each is securely attached. The bearings of the motor are shown in Fig. 299.

This construction is known as a squirrel cage winding. The same general form of construction is used for induction motors of all capacities, being extremely simple, rigid and durable.

The design and principles governing the construction of induction motors are particularly favorable to maintaining good efficiencies at low loads, which insure a high all-day efficiency, as in general service motors operate at light loads much of the time.

The variation in speed between no load and full load is very small, a characteristic of great value in many instances.

An induction motor may be started by throwing it directly on the line by means of an ordinary switch, or by applying a low voltage until the motor acquires a fair speed and then, by successive steps, raising the potential until it reaches its normal value, at which time the terminals of the motor are connected directly across the supply circuit and the starting device is cut out.

DIRECT CONNECTED POWER UNITS.

Direct connected power units have been almost exclusively adopted for central stations. For small isolated plants also the advantages of this type are so well recognized that the direct connected unit is now being generally used where the output is even as low as 20 Kilowatts. The economy of space, low cost of maintenance, simplicity and ease of manipulation, are some of the reasons why this type is chosen in preference to the less expensive belt driven machines.

The generators illustrated in Figs. 300, 301, 302 and 303 embody all the well-known features peculiar to this type of machine. They are as compact as is consistent with low temperature rise and sparkless operation. They meet the standard speeds and outputs which have been

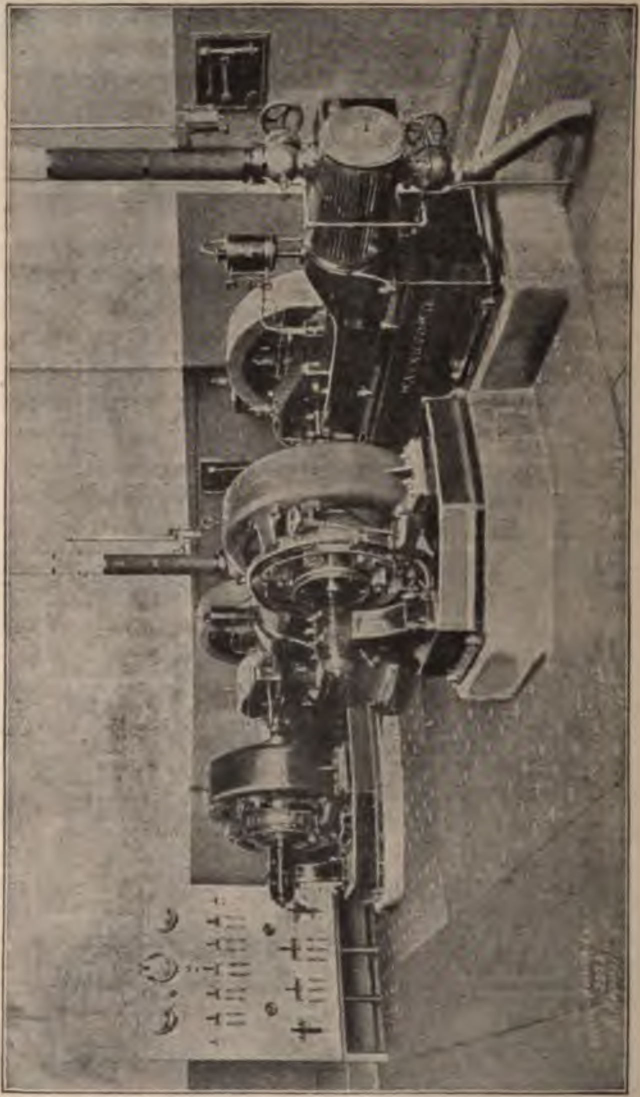


FIGURE 300.

generally adopted by the engine builders, and also meet the test standards recommended by the American Institute of Electrical Engineers.

The efficiency is high at light loads as well as at full load. Special attention is given to ventilation in order that the generators will carry large overloads for long periods without injury. These are very desirable characteristics in a lighting power generator.

The construction of the magnet frame consists of internal flanges, which insure ample stiffness and give a finished and pleasing appearance to the machine. The frame is split horizontally, the halves being accurately lined by dowel pins and held together by bolts. The feet are drilled for holding-down bolts and in addition have leveling screws for accurately adjusting the magnet frame.

The poles are round and of steel cast welded in the frame so as to make a perfect magnetic joint.

Each pole is fitted with a cast iron removable shoe designed to produce the best distribution of the magnetic flux over the armature surface. It also serves to retain the field coils in position.

The air gap or clearance between the armature and pole face is large. This is a very valuable feature, as it tends to reduce any bad effects resulting from a slight displacement of the armature from its true center. A slight settling of the foundations or perhaps the ordinary wear of the journal boxes may in time permit the armature to become slightly out of center of its field. A slight displacement in a machine with a large air gap will be only a small percentage of the total clearance. The same displacement in a small air gap will be a large percentage of the clearance and result in causing a powerful attraction of the armature toward the nearest poles. This will strain the shaft and cause over-heating of the bearings

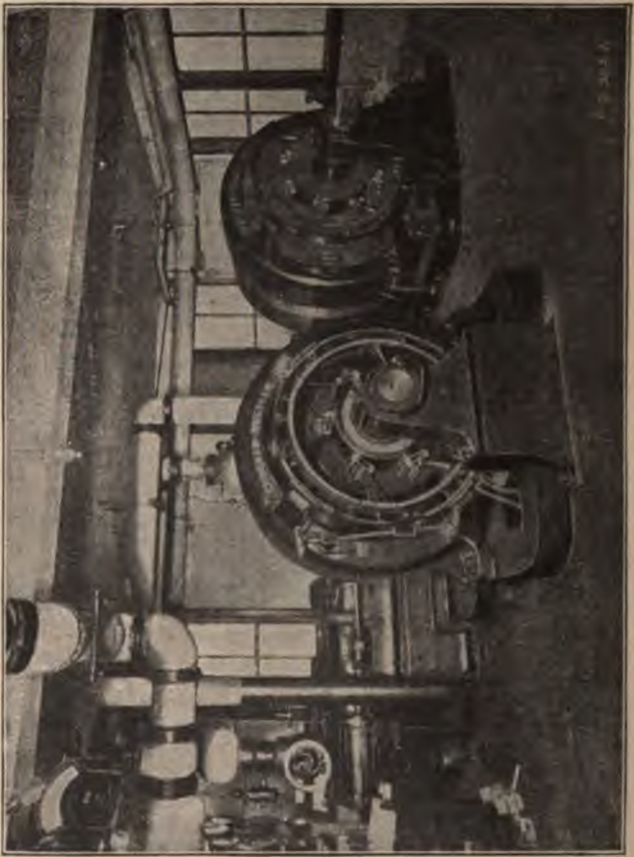


FIGURE 301.

and disturb the magnetic and electric balance so that there will be excessive heating of the armature and sparking.

The field coils are compound wound, the shunt and series coils being separated, and sub-divided in the large sizes. Each section is wrapped with heavy tape and thoroughly impregnated with insulating varnish. The coils are thus protected against mechanical injury and also from being permanently injured by moisture. The various sections are separated from each other and the frame by wooden spacers. This form of construction permits of free circulation of air between and around the coils, which dissipates very effectually the heat generated in the coils.

The shunt coils are supplied with substantial terminals marked so that the proper connections can easily be made. The series coils are wound with copper strip and the connections between them are made by interleaving the multiple strips, thereby securing an excellent electrical contact.

The armature spider is designed so as to avoid internal shrinkage strains of the casting. The hub will be bored to conform to the generally accepted standard sizes of engine shafts, which the purchasers supply. Any considerable deviation from a standard size may require a special spider casting, which would affect both delivery and price.

The arms attached to the hub support the toothed laminations and form the armature core. These laminations are of selected sheet steel of high magnetic quality.

The windings are without joints, except where connected to the commutator. The conductors consist of round or flat wire taped and varnished. The insulation between the conductors and the core consists of a very

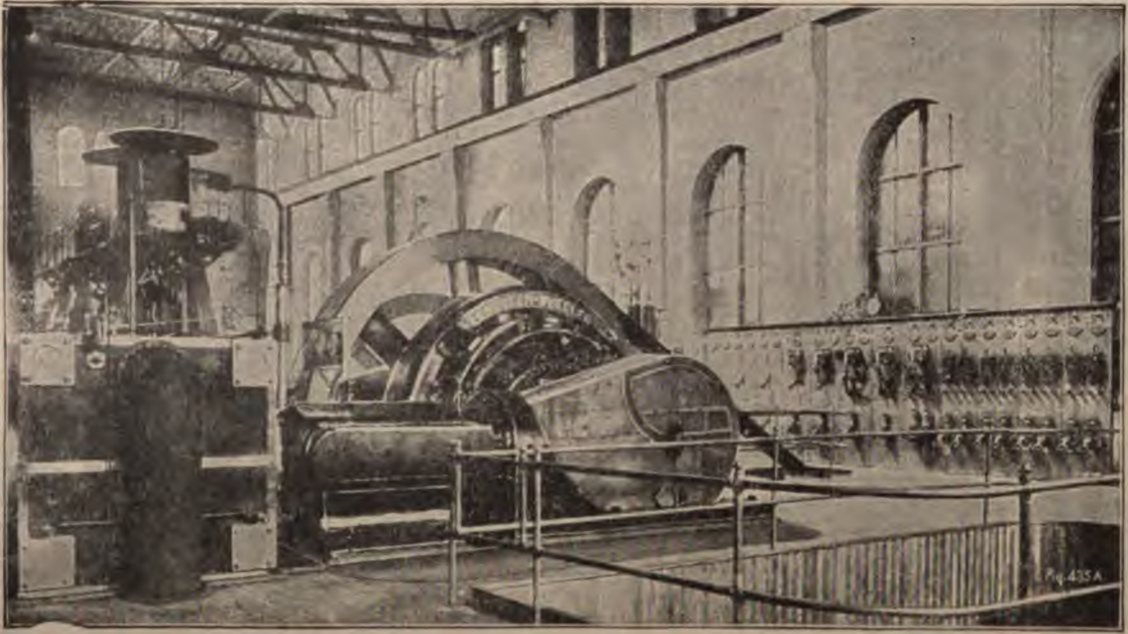


FIGURE 302.

tough material which possesses high dielectric strength to meet the insulation requirements and which will not deteriorate when subjected to a much higher temperature than that guaranteed, nor be permanently injured if exposed to dampness. The conductors on the small sizes are retained in place by band wires, and on the large sizes by wooden wedges driven in the niches of the slots, which renders band wires on the core unnecessary. Band wires are provided on the ends of the windings on all sizes

The core and winding are thoroughly ventilated to insure cool running.

The spider is mounted on an extension of the armature spider, and is independent of the shafts and the commutator bars are of the highest grade of hard drawn copper, extra deep, and designed to give a maximum wearing depth. The larger sizes have a sectional front clamping ring which permits removing a few bars without disturbing the others.

The commutator surfaces are very liberal, and the brush density low. The average volts per bar is very low, and the machines possess excellent commutation characteristics. As a result the commutator wear is almost negligible.

The cast iron rocker ring is supported in bracket guides bolted directly to the magnet frame, and has a tangential screw and hand wheel for shifting simultaneously the position of all brushes. The brush holders are supported on brackets bolted to and thoroughly insulated from the rocker ring.

The brackets which carry each set of brush holders are individually adjustable. By this adjustment a perfect balance can be secured between the electrical circuits composing the windings, without resorting to any special compensating device in the armature. The remarkably

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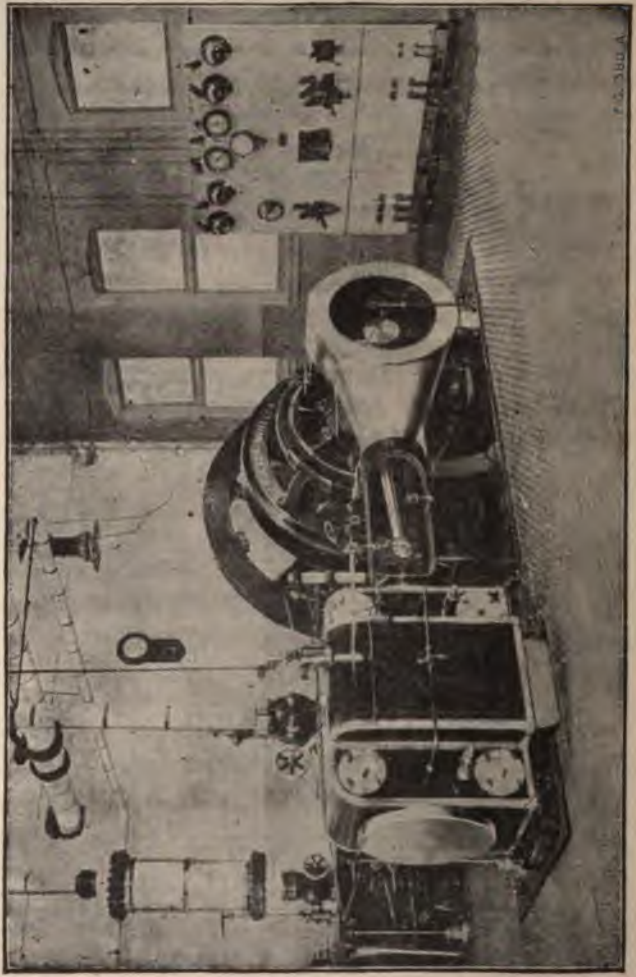

FIGURE 303.

perfect electrical balance thus obtained insures better behavior of the machine and therefore reduces commutator and brush wear to a minimum. All the positive sets of brush brackets are connected to a copper bus ring mounted on one side of the rocker ring and all the negative brush brackets to a similar ring on the other side of the rocker ring.

The brush holders are of the parallel type and amply proportioned for the current. They are individually adjustable and will not allow the position of the brush to change as it wears away. The brush is held rigidly in its box and there are no sliding contacts or springs through which current has to pass in its path from brush to bus bar.

These generators are so constructed as to run in multiple with other like machines, and when so connected and once properly adjusted, each will carry its share of the load.

The compounding is adjusted by a suitable shunt placed across the terminals of the series field. This shunt can be easily modified or replaced by another if a change in compounding be desired.

Although machines of this class operate under variable load conditions, they are guaranteed to run continuously at full load without heating more than 40° C. in any part above the surrounding air. They will run at 25 per cent. overload for two hours immediately following full load run with an additional rise of not more than 10° C. in any part. These generators will operate without sparking, from no load to full load with fixed brush position, and will stand 40 per cent. overload for a short period and 100 per cent. momentary overload without injurious heating or sparking.

DIRECT-CONNECTED MOTOR DRIVEN MACHINERY.

No department of electrical science has advanced the art of manufacture in its many branches to the same extent as the introduction and development of the electric motor. Today, practically speaking, every modern factory is furnished with electric motors, and the long lines of heavy engine driven shafting and counter-shafting installed in manufactories of older date are fast being superseded by electric motors.

The advantages of electric drive are numerous and hard to overestimate, but so much has been written on this subject that it is unnecessary to enter into details.

Broadly speaking, it is modern practice to provide individual motors for heavy machines performing either intermittent work or operations requiring a large range of speed variation; and motor driven shafts for distributing power to small groups or batteries of machines. A prime factor in the use of electric motors is the elimination of idle work, such as turning shafts and belting irrespective of the work they are performing. Whether individual motors are to be used or machines are to be driven in groups must be determined in each specific case. No general rule can be laid down. It is obvious that driving machines in groups requires an approximate knowledge of the power used by each tool, before the size of motor to be installed can be determined. Again, if a machine is performing work requiring a large range of power, the maximum power requisite may greatly exceed the average load. In such cases individual motors are recommended.

Paramount among the numerous other advantages gained by the adoption of electric motors in preference to other methods may be cited:

The motor is running only when actually doing work.

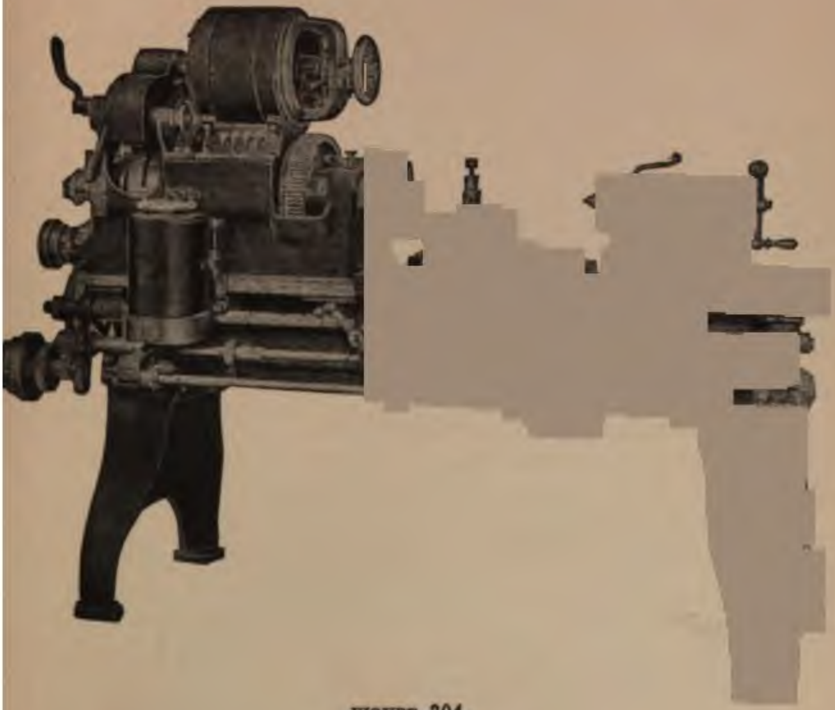

FIGURE 304.

The energy consumed in the leads from the prime mover to the motor is negligible when compared with the losses due to friction and belt slippage in other methods of power transmission.

The motor may be placed in any position and can b made absolutely waterproof when conditions demand.

The space which would otherwise be occupied by overhead belting and shafts is available for the operation o overhead cranes.

It is possible to work one or two machines only without running any idle shafting.

The electric motor requires practically no attention.

Fig. 304 shows a one-horsepower motor operating a 16-inch engine lathe.

ENGINE DRIVEN REVOLVING FIELD ALTERNATOR.

A revolving field alternator is shown in Fig. 305.

The Field. The field spider is cast in one piece with the rim. The low speed permits the poles to be bolted to the spider: a simple construction that facilitates removal of the poles when necessary. The hubs can be bored to the diameters generally called for in engine builders' specifications.

Foundation Plates. Although these generators are designed for mounting on an extended engine base, at a slight additional expense cast iron foundation plates can be provided.

Collector Rings. The collector rings are made of cast iron, split in two pieces, and are supported by insulated pins mounted on a small cast iron shell on the shaft.

When a direct connected exciter is used, the armature is mounted on the shaft close to the revolving field. The magnet yoke is bolted to the generator armature frame, being split into two pieces so that it can be easily removed. The exciters are very conservatively designed, and are more than capable of exciting the generators

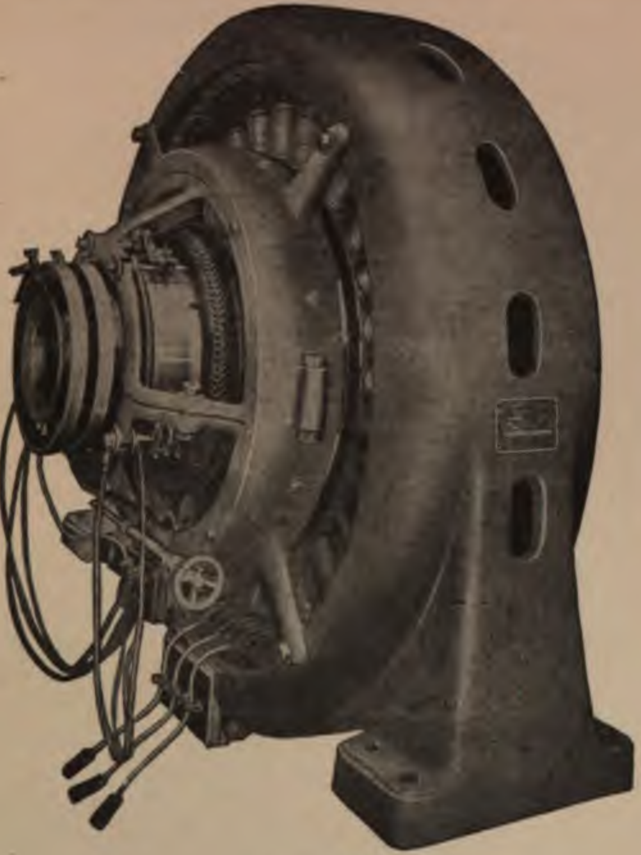

FIGURE 305.

under all conditions of load, provided the speed is normal. The advantages of having an exciter of very liberal design are well known, such exciters being particularly desirable when the generator load is of low power factor. The exciters are especially adapted for use with the TA voltage regulator, and when thus used the voltage at the generator terminals is kept practically constant through considerable changes in speed or in the character of the load.

Brush-Holder Support. On machines having direct connected exciters, the brush-holders for exciter commutator and generator collector rings are supported by a brush-holder yoke which is part of the exciter. On machines without direct connected exciters, the brushes for collector rings are supported by a yoke which is mounted on a groove in the outboard bearing.

Phases and Voltages. The standard designs are adapted to three-phase or two-phase windings without change except in the coils and armature punchings, the exciter and all accessories being the same for both. No single-phase windings have been standardized, the intention for the present being to use three-phase windings for cases where single-phase machines would ordinarily be required.

Temperatures. These machines will carry continuously their full rated capacity of two- or three-phase non-inductive load, the temperature of no part of the machine exceeding 40° C. above that of the surrounding air. They will carry 25% overload for two hours with a rise of temperature not exceeding 55° C. All machines with three-phase windings will carry 75% of their rated polyphase capacity in single-phase current, with the same temperature rise as given for two- and three-phase ratings; or will carry the full rated capacity in single-phase current for a period of three hours without injurious heating.

Designs for the following potentials have been made:

Three-phase, 240, 480, 600, 1150, 2300.

Two-phase, 240, 480, 1150, 2300

Machines with three-phase windings arranged for 2300 volts can be more promptly delivered than those wound for other potentials. For factory plants 480 volt generators are recommended.

WIRING POWER CIRCUITS IN MANUFACTURING PLANTS.

The efficient operation of a power plant depends to a large extent upon the proper installation and distribution of the power. Unless a plant is properly wired, the losses will greatly reduce the total efficiency of the entire plant. The subject of wiring is so wide in scope and the conditions under which machines are installed are so varied that it is impossible to lay down a fixed and fast rule that will cover all classes of manufacturing plants.

The flexibility of electrically driven machines and the ease with which they can be transported from one place to another is becoming an important factor in machine tool work, and in laying out the wiring of a new plant due consideration should be given to this desirable feature of using portable machines.

The plant should also be wired with the idea of extension in mind, as very seldom a plant is erected without the subsequent addition of a large number of extra machines, more than were originally planned.

The wiring of a shop should be of ample carrying capacity to carry the power without a drop in voltage to exceed, say, 3 per cent. when the machines are in practically continuous operation but in plants where the motors are only used a portion of the time, a somewhat larger drop could be allowed on the line, as the loss is only going on while the motor is in operation, thus reducing the necessary investment for copper in wiring. Care must be taken, however, to make the wire of ample carrying capacity to meet the Underwriters' rules governing in the locality. The wire should always have good mechanical strength, even though a smaller sized wire might be large enough to carry the current.

The best practice divides the wiring into sections or blocks, protecting each section by switches and fuses and cross connecting same so that in case of accident to the wiring on any particular section, this defective member can be cut out and the rest of the shop operated unhampered by the defective piece. The old method of wiring up shops was to put in one long feeder and if anything happened to this feeder or any tap connected to it, the entire plant was liable to be shut down until repairs could be made.

The additional cost of wiring up a plant on the sectional system over the single main system may reach as high as 75 per cent. This increased expenditure, however, is a very good investment, as it provides for the independent distribution to each division and insures impossibility of shut down of plant through any cause relating to wiring.

When it becomes necessary to make extensions to a plant or to add extra machines, more than were originally figured upon, the shop that is wired up on the sectional plan can have more copper added to any particular section in case the load is increased upon it more than was originally planned for. This would not necessitate the enlarging of all the wiring as might be the case if the plant was wired up on one large feeder, as the additions generally come at a point farthest away from the source of power.

Open type wiring on suitable porcelain knobs would be the cheapest and generally satisfactory, but for manufacturing plants, the following scheme of distributing the power circuits throughout the plant is recommended: Place the wires underneath the floors and bring the taps up through the floors to the motors, providing the motors are placed upon the machines or upon the floors. This does away with wires coming down from the ceiling to the motors, obstructing the light or interfering with cranes or with the handling of material above the machines.

In order to do this, the ground floor must be wired underneath in conduit. The motors that are placed upon the ceiling or bolted to posts or side walls could be wired from the mains that are strung on the ceiling.

In shops where large castings are machined, it has become the practice in some cases to carry the machine tools to the work, instead of the work to the tools. In such shops it would be advisable to wire up the divisions where this class of work is done with a number of flush receptacles of sufficient capacity to furnish power to the largest machines. These receptacles should be distributed, either on the floor or on suitable posts, so that a motor could be connected up without leaving great lengths of loose wire exposed on the floor.

The most desirable voltage for the majority of plants is 220 volts, excepting that in cases where there are only a few machines installed and where the area over which they are distributed is very limited, 110 volts is sometimes used. In other cases where the motors are scattered over a large area, 500 volts is used to better advantage.

STEAM TURBINE PRACTICE.

The application of the steam turbine to driving electric generators is a comparatively recent step in modern progress. It does not seem so very long ago that electrical engineers were evolving the slow speed generator for

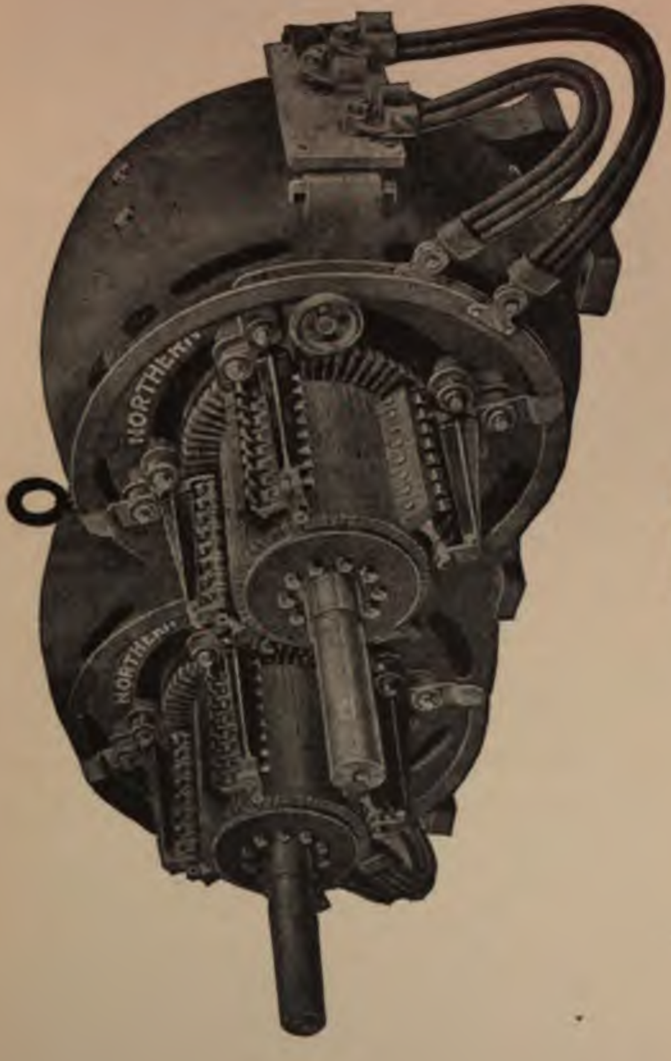

FIGURE 306.

direct connection to engines of the Corliss type. Now an attempt is being made to return to the old high speed practice, and the question is largely one of reducing the speed of turbine to a point where the operation of the generator will not be attended by danger due to the great peripheral speed of the armature.

Fig. 306 illustrates this type of construction, twin generators for connection to, and operation by steam turbines. In addition to producing a generator of great efficiency and durability, the engineers have designed a machine which is very compact and pleasing in appearance.

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